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USER'S MANUAL FOR FVSOLVR AND FVPLT: FIELD SOLVING AND PLOTTIN--ETC(U)
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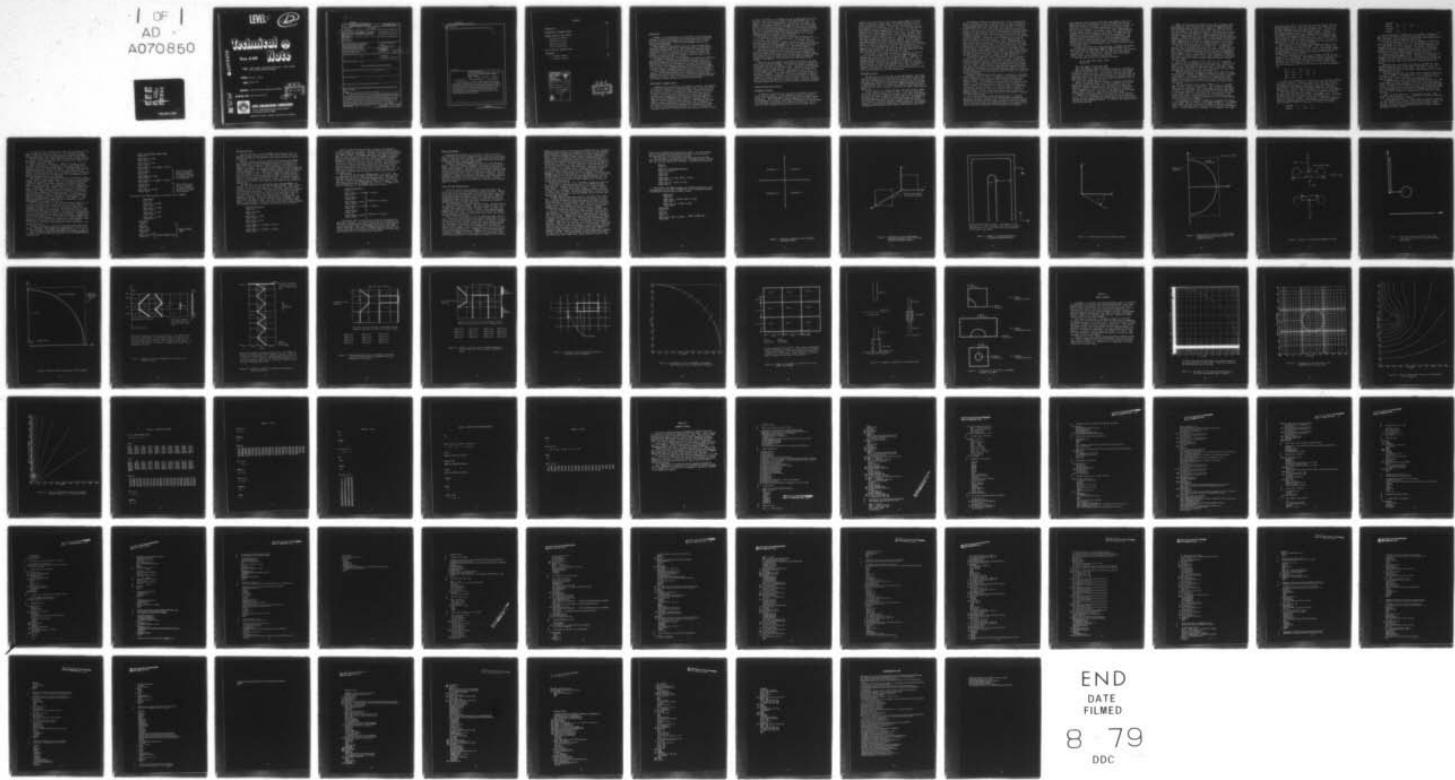
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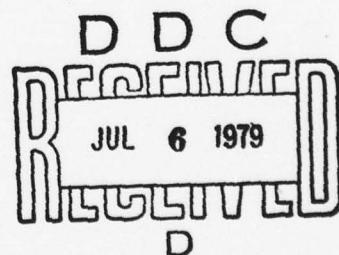
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INTRODUCTION

FVSOLVR is a two-dimensional finite difference field solving algorithm for the calculation of electric field and potential distribution. The nodal solutions from FVSOLVR can be used to plot electric field lines and/or equipotential lines using the CALCOMP plotter and the companion program FVPLOT.

These programs were developed as part of a Navy research effort concerning insulators employed in large antenna arrays. These antenna insulators are subjected to severe electrical field conditions which occasionally result in arcing, corona, and heating or burning of the insulators. In order to determine causes of insulator failures and evaluate alternative designs it is helpful to know the electric field distribution associated with each insulator.

The general capabilities of the programs, the theoretical foundation, and a discussion of possible applications can be found in the Civil Engineering Laboratory Technical Note N-1502, "Computer Technique for Calculation of Potential in Multidielectric Media," by Kwang-Ta Huang, Brian R. Milner, and Andrew W. McClaine. The intention of this manual is to provide a user of FVSOLVR and FVPLOT with the detailed information required in order to implement problem solutions with these programs.

The programs described herein are written for use with a Fortran IV compiler. The program versions listed in Appendix B have been used successfully on the CDC 7600 computer at the Lawrence Berkeley Laboratory, Berkeley, California. Users are cautioned that minor modifications may be necessary if these programs are used with other systems.

DESCRIPTION OF PROGRAM FVSOLVR

FVSOLVR solves problems which are geometric in nature. The geometry of the solution region can be described using either a cartesian coordinate system or a cylindrical coordinate system. The solution region in the cartesian system is a rectangle with a side parallel to the x-axis. In Figure 1, the x-axis can be either of the two axes shown and the solution region may generally include parts of any of the quadrants. (Some versions of FVSOLVR which are designed to take advantage of the symmetry of certain problems require that the rectangular solution region be entirely within the first quadrant.) The rectangle describes a plane in space, perpendicular to the z-axis, with z coordinate z . The condition required for this problem to be two-dimensional is that, as z varies, the field solution does not vary. That is, any similar rectangle translated in the plus or minus z direction will have the same

solution. See Figure 2. An example of such a problem might be a capacitor plate within a housing, as shown in the cross-sectional view of Figure 3. The z-axis is perpendicular to the plane of the paper. The geometry in any plane parallel to the paper must have the same configuration. Idealizations usually must be made in cases such as this since the capacitor plate and housing do not have infinitely long z dimensions. But if d is the largest gap dimension and the actual z dimension of the capacitor is greater than $20d$, then experience dictates that the two-dimensional solution is usually a good approximation, until one gets closer than $20d$ to a boundary in the z direction.

The cylindrical coordinate system, illustrated in Figure 4, can also be used. The solution region is either a cylinder of radius $r = r_1$, or a cylindrical section from $r = r_0$ to $r = r_1$. In either case, the solution region has a height, h , which is measured in the z direction. The z-axis must be an axis of symmetry; that is, the geometry and solution are two-dimensional and independent of θ . The geometry can vary with r and z and the function to be solved is $\phi = \phi(r, z)$, with $\partial\phi/\partial\theta = 0$.

The program incorporates the useful characteristics of variable grid spacing and variable dielectric properties, thus allowing multi-dielectric medium problems to be solved with economy of computer time. The program also has the capability of solving anisotropic media problems. Greater detail about the inner workings of the computer program and relevant electromagnetic theory can be found in CEL Technical Note N-1502.

Input data for the programs are developed and entered in the same way for both coordinate systems. When using the cylindrical system, the z-axis must be an axis of symmetry. Figure 5 illustrates an example of the solution region in the cylindrical case. The known circular boundary in Figure 5 will be explained later. The r-axis may or may not have a plane of symmetry passing through it perpendicular to the z-axis. In the cartesian system, the y-z plane and/or the x-z plane may or may not be planes of symmetry. Input data include grid coordinates, dielectric values (which can vary throughout the grid system), dielectric material boundaries, and known potentials or electric field conditions. Development of program input data will be shown by example, using the cylindrical coordinate system and solving an electric potential distribution problem.

PROBLEM SOLUTION USING FVSOLVR

Statement of Problem

A potential field solution for the region surrounding two parallel corona rings is required. In this problem, a potential is applied across the air gap separating the corona rings, which are metal toroids. See Figure 6. Each toroid has an outside diameter of 20 inches and an inside diameter of 10 inches. Each toroid is suspended by a pipe attached to a thin sheet of metal welded to the center of the toroid. In this case, the z-axis coincides with the center line of the pipes and is

perpendicular to the planes of the toroids. As an example of an application, in Appendix A of this manual, the FVSOLVR program is used to solve this particular problem. The top ring and pipe consists of conducting material at a potential of +100 volts, and the bottom ring and pipe linewise, except at a potential of -100 volts. Not only does this problem have rotational symmetry about the z-axis, but it also has symmetry across a plane perpendicular to the z-axis. The plane defined by $(z=0, r)$ is a mirror symmetry plane. Thus, solving the upper right hand quadrant will give solutions for the other three quadrants as well. This solution region is shown in Figure 7. Significant computational advantage is gained when solving just one quadrant. Only one-fourth as many equations need be solved; therefore, computer costs are greatly reduced. Problems such as this, which have mirror symmetry from top to bottom, will have an equipotential line about which this mirror reflection will occur in the two-dimensional solution. The potential of this symmetry line is always half the sum of the upper and lower potentials. Since the upper potential is +100 volts and the lower potential is -100 volts, the voltage at the center ($z=0$) line is 0 volts.

The voltages in any problem can always be normalized so that this central line has a voltage value of zero volts simply by adding or subtracting a constant value from all known voltages. In general, the relative voltage levels can be shifted by any constant value. The FVSOLVR program requires that all voltages be non-negative. If it is desired to solve a problem involving negative voltages, all voltages must be shifted to eliminate the negative values. After the solution is obtained, the values can be shifted back to the original levels to obtain the true solution. The shape of the flux and equipotential lines will not be affected by this kind of manipulation.

Development of Data

The generation of the input data is performed manually, and usually requires the preparation of a good drawing of the solution region. Note that use of graph paper will facilitate the preparation of the drawing. Grid lines are constructed on the drawing, keeping in mind that any type of boundary must consist of straight line segments beginning and ending on nodes of grid lines. The circle which represents the corona ring in Figure 7 will in fact be a series of straight line segments approximating the circle.

At this time, we will examine boundary conditions, which are known at $r=0$ (viz. $\partial V/\partial r=0$) and at $z=0$ (viz. $V=0$). If the grid region does not include the axis of symmetry but begins at some radial value greater than zero, the boundary conditions for that edge of the grid region must be given explicitly. (A means for inputting this data is described in the section which discusses the input variables NPOTS, POT, NLLINES, etc.) But as r and z go to infinity, boundary conditions are not known. A means for treating such problems will be presented here. The theoretical basis for this approach can be found in CEL Technical Note N-1502.

The boundary conditions at large values of r and z can be approximated to sufficient accuracy by considering that at large distances the corona ring gap appears like a point gap. The point gap arrangement is a simple geometry which has a well-known field distribution. At large distances the electric flux lines around a point gap form near-perfect circles. Such an electric flux line can be used as the necessary boundary condition at large distances. Thus, at some distance, which experience dictates to be 10 to 20 times the distance of the gap between the rings, a boundary, assumed to be a circle, is introduced. This circular boundary is shown in Figure 8. Inside the circle, the medium is air with the relative dielectric value taken as unity. In the region outside the circle, the dielectric value is taken to be zero. Mathematically, this means that the region outside the circular boundary does not affect the region within the circular boundary. At least two grid lines are needed outside the circular boundary, one in the r direction and the other in the z direction. These two grid lines coincide with the edges of the solution region shown by dashed lines in Figure 8. The circular boundary and zero dielectric obviate the need for explicit boundary conditions at the edges of the solution region. (Again, it might be noted that this circular boundary is a series of straight line approximations.)

Variable grid spacing is used in the program. This is extremely valuable in that proper use of such a scheme can reduce the number of equations which must be solved. Experience is needed to predict where fine grid spacing is needed and where coarse grid spacing will suffice. A "rule of thumb" is that regions in the neighborhood of the gap, where small radii occur, tend to have the highest voltage gradients and therefore need more grid points for good approximations. Regions far from the gap tend to need fewer grid lines for good approximations. Experience with the program and actual experimental results will aid in arriving at optimal grid designs.

Boundary lines between different dielectric regions are constructed within the grid system. These are composed of line segments constructed either horizontally, vertically, or diagonally between adjacent grid points. Regions of known potential can be assigned any convenient dielectric value. This freedom is allowed because, for regions of known potential, the program does not solve equations involving dielectric values. However, for completeness of the data arrays, all regions must be assigned a dielectric value. It is most convenient to assign to a region of known potential a dielectric constant equal to that of an adjacent region. In such a case, there does not exist a dielectric boundary between the two specified regions since the dielectric constants are taken to be the same.

If a problem includes a conducting medium which is of unknown potential, the region occupied by such a medium must be assigned an appropriate dielectric constant value. Satisfactory results can usually be obtained by assigning to the conducting region a dielectric constant which is very much larger than (and nearly infinite with respect to) the relative dielectric constants of the surrounding insulating media.

Since computers cannot represent infinitely large numbers, there is an upper bound on the value which may be used to represent the relative dielectric constant of the region. If the value chosen is too large, it could result in over or underflow problems with the computer during execution of the program. If the value chosen is not large enough, it will not appear "infinite" with respect to the other relative dielectric constants in the solution region of the problem. The symptom of this malady will show up in the potential distribution solution, where the whole of the conducting medium will not be at an equipotential. The optimum dielectric constant value for a conducting medium of unknown potential will be machine dependent and the user should determine a suitable value by trial and error method. Satisfactory results have been achieved with a CDC 7600 computer using a relative dielectric value of the order of 10⁸.

The data deck format will now be explained. Throughout this manual, in the discussions pertaining to computer program variables such as HX(I), HY(J), NX, NY, NEPR, NEPZ, BDR(I,J), BDZ (I,J), etc., any reference to x holds true for r and vice-versa. The same relationship exists between y and z. The information for the data deck can be obtained almost totally from the drawing of the problem.

The first data card has the following information:

NX, NY, NEPR, NEPZ, IFSKIP, IFBDY
Format 6I4

NX is the number of axial grid lines.

NY is the number of radial grid lines.

NEPR is the maximum number of dielectric boundaries that might be encountered in any given row. A row is defined here as a slot between two adjacent radial grid lines. See Figure 9. Note that there must always be a dielectric boundary which coincides with the axial grid line of maximum radial value. For the grid in Figure 9, the proper value of NEPR is four (4), since there are four dielectric boundaries in the Ith row and no other row has more than four.

NEPZ is the maximum number of dielectric boundaries that might be encountered in any given column. A column is considered to be a slot between two adjacent axial grid lines. See Figure 10. There must always be a dielectric boundary which coincides with the radial grid line of maximum axial value. For the grid in Figure 10, the proper value of NEPZ is ten (10). This value is determined by the Jth column, which has more dielectric boundaries than any other column.

IFSKIP is an indicator used to test input data (to be explained later). Briefly, if IFSKIP \neq 0, the program merely reads the input data and sets up the boundary conditions so that the user may verify that the problem has been programmed correctly. If IFSKIP=0, the program executes the solving algorithm.

IFBDY is an indicator which identifies the type of boundary conditions which are to be used for the top (radial) and right-hand (axial) grid boundaries shown as dashed lines in Figure 8. IFBDY=0 indicates that the boundary conditions are to be treated implicitly, as for the circular boundary in the example of Figure 8. This means that it is not necessary to provide the potentials along the top and right-hand boundaries explicitly as input data (i.e., these boundary potentials can be ignored). IFBDY \neq 0 indicates that potentials along the top and right-hand boundaries are given as input data. This is usually done if the solution region happens to be a fine mesh in a section of a previously solved large, rough mesh grid, so that the boundary potentials can be interpolated from the large grid solution. (Further details are given later.)

The next set of information read is HX(I) for I = 1 through NX. HX(I) are the r coordinates of the axial grid lines. The HX(I) must be ordered in increasing magnitude and must all be greater than or equal to zero. HX(I) is always the distance from the axis (line) of symmetry to the Ith axial grid line. The format for each punched card having HX(I) data is 10F8.0. When a decimal point is used, a maximum of 3 digits to the right of the decimal point is taken; digits beyond the third decimal place are rounded off. Units of measure should be scaled to conform with this format.

The next set of information read is HY(J) for J = 1 through NY. The HY(J) are the z coordinates of the radial grid lines. HY(J) must be ordered in increasing magnitude and can be greater than, less than, or equal to zero. The format for HY(J) data cards is also 10F8.0. Again, only the first three digits to the right of the decimal point are taken and additional digits to the right are rounded off.

HX(I) always represents distances measured in the radial direction for cylindrical problems. Axisymmetric problems must always be oriented in this manner. For problems represented in the cartesian coordinate system where no grid boundary coincides with a symmetry plane, the problem can be oriented in any manner with respect to HX(I) and HY(J). However, the program execution will be faster and less costly if NX is less than NY.

The next information that is read is BDR(I,J) for J = 1 through NEPR, for each I from I = 1 through NY-1. This information indicates where dielectric boundaries exist in the radial direction. The program "searches" the rows (radial slots) between adjacent radial grid lines for dielectric boundaries. The first index (I) is the row index, which is the integer value of a given radial slot, starting with 1 at the bottom of the region. The second index (J) is the dielectric index which indicates the Jth boundary encountered in the Ith row when moving outward from the axis of symmetry.

The assignment of the values of BDR(I,J) is explained with respect to the example shown in Figure 11, where NEPR=3 and NY-1=4. If a boundary exists axially (parallel to the axis of symmetry), BDR(I,J) is given a value of two times the index if the axial grid line on which the boundary occurs. If the boundary line is diagonal, it is assigned a value equal

to the sum of the indices of the two axial grid lines between which the diagonal boundary occurs. This will always be an odd integer, whereas all axial boundaries will always have even BDR values. If a given row has fewer than NEPR boundaries, dummy boundaries must be placed at the last axial grid line to satisfy the computer program. Therefore, in this example, NEPR=3 requires that a dummy boundary be placed in row 3 at grid line 6 to complete the BDR(I,J) array. If, for example, NEPR were to equal four and NY-1 were to equal fifty, four dielectric boundaries would have to exist for each one of the fifty rows. It is quite possible that, in many rows, several boundaries will be "stacked" at the last grid line in order to satisfy the program.

Another example of the assignment of the BDR(I,J) values is illustrated in Figure 12. For this case, NEPR=4. The format required for the input of the BDR(I,J) values is 2014. (Thus, in the present example, all of the BDR(I,J) data would go on one card.) In general, NY-1 groups of NEPR integers are used to describe the boundaries that might be encountered in the radial direction.

The next information read is a series of numbers, KO, KN, KK, and EPSR(K) for K = 1 through KK. These numbers are used to assign dielectric values to the regions identified by the radial boundary search just described. The information is governed by the order of appearance of the dielectrics. For example, in Figure 12, for rows one, two, three and four, respectively, the dielectric values, in the order of appearance are:

Row 1:	1.0	10.0	1.0	
Row 2:	20.0	1.0	10.0	1.0
Row 3:	20.0	1.0	10.0	1.0
Row 4:	20.0	1.0		

A given order of appearance is referred to as the dielectric sequence for the particular slot. KO is the index of the first row in which a new sequence of dielectrics is encountered. KN is the index of the last row having that same sequence, with the provision that if KN-KO is greater than 1, all rows between the KOth and KNth rows also have the same dielectric sequence. KK is the number of dielectrics in the sequence.

The first card to be read for this series of numbers contains KO, KN, KK for the first dielectric sequence. The format is 3I4. This is followed (on the next data card) by the values EPSR(K), for K = 1 through KK, of the dielectric constants in their order of appearance. The format for this data is 16F5.0. This process is repeated for successive dielectric sequences appearing in the solution region (until KN=NY-1). For the example of Figure 12, this part of the data is as follows:

KO,KN,KK	1	1	3
EPSR(K)	1.0	10.0	1.0

KO,KN,KK	2	3	4	
EPSR(K)	20.0	1.0	10.0	1.0
KO,KN,KK	4	4	2	
EPSR(K)	20.0	1.0		

Since the sequence of dielectrics in this example is identical for Rows 2 and 3, the values for these two rows can be read in together. This "shorthand" is quite useful for most problems, where many successive rows will contain the same sequence of dielectrics.

A similar procedure is used for input of boundaries in the axial direction search. The BDZ(I,J) for J = 1 through NEPZ, for each I from I = 1 through NX-1 are read. The rules which govern the BDZ data are analogous to the rules for the BDR data. The program "searches" the columns (axial slots) between adjacent axial grid lines for dielectric boundaries. BDZ(I,J) represents the Jth boundary in the Ith column. There are NX-1 groups of NEPZ boundaries read in format 20I4.

Another set of KO's, KN's, and KK's are then put into the data set with their accompanying EPSZ(K) values. The EPSZ is the dielectric constant value in the radial direction. This value need not be the same as EPSR at the same point, which represents the dielectric constant in the axial direction. This allows anisotropic medium problems to be solved.

Boundaries which are radial do not appear in the BDR(I,J) array. Boundaries which are axial do not appear in the BDZ(I,J) array. Only diagonal boundaries appear in both arrays. This fact is useful in checking data accuracy using the boundary check program (to be discussed in a subsequent section).

The quantities NGX, NGY, VG, and GH, which are explained below, are read only if IFBDY \neq 0. The IFBDY \neq 0 option is for solving the potential distributions in a finer grid region (i.e., with a finer mesh) in the lower left-hand corner of a previously solved coarse mesh.

If IFBDY \neq 0 the next data card contains NGX, NGY is format 2I4. NGX is the number of "coarse" axial grid lines in the "fine" grid solution region, including the axial boundary of the fine grid region (which must also be a "coarse" grid line) and the r=0 axis. The "coarse" grid lines are those that were used in the initial solution of the complete problem (i.e., with IFBDY=0) that was run before the IFBDY \neq 0 option is to be executed. NGY is defined in an analogous manner for the coarse radial grid lines.

Next, the values GH(I) for I = 1 through NGX are read. These values are the coordinates of the r intercepts of the coarse axial grid lines. The format for GH(I) is 8F10.3.

The voltages VG(I), for I = 1 through NGX are read next. These are the node voltages along the radial coarse grid line which coincides with the top, radial grid line of the fine grid solution region. These voltages are obtained from the previously solved coarse grid solution. The format for VG(I) is 8F10.3.

In a like way, the coordinates are read for the z intercepts of the coarse radial grid lines, viz. GH(J), for $J = 1$ through NGY, format 8F10.3. Likewise, the voltages along the right side axial boundary of the fine grid, VG(J), for $J = 1$ through NGY are ready in format 8F10.3.

NGX, NGY, GH(I), VG(I), GH(J), VG(J) are the only optional data for the program. The following information is required in all cases, irrespective of the value of IFBDY.

NPOTS is read next, in format I4. NPOTS is the number of known potentials in the problem. For example, if part of the region has a voltage of +100 volts, and elsewhere there is a grounded region, with no other known potentials present, then NPOTS=2. The known potentials must always be greater than or equal to zero; no negative potentials are allowed. If negative potentials exist, the absolute value of the minimum potential must be added to all known potentials in the problem so that there are no negative potentials remaining.

Once NPOTS is read, the known potentials must be assigned to those nodes at which the potentials are known. This is done in a loop performed a number of times equal to NPOTS. The first information needed is POT, format F8.0, which is the potential assigned to a region (or several regions) of known potential. The "region" may also be a single point (i.e., a single node). Next, NLines, format I4, is read. NLines is the number of rectangles needed to describe all regions of the particular potential POT. These rectangles need not be connected. An example of how to calculate NLines will be given with the aid of Figure 13. The fourteen dark dots are points of known potential. In this example, it takes two rectangles to describe the region of known potential. Note that one of the rectangles is "collapsed" to a line segment. A point would be considered as a rectangle that has "collapsed" to a point. Thus NLines=2 in the example of Figure 13.

Next, the quantities L1, L2, M1, and M2 are read in format 4I4. L1 and L2 are the indices of the axial grid lines that form "edges" of a rectangle of potential POT. L1 must be less than or equal to L2. Likewise, M1 and M2 are the indices of the radial grid lines that form the remaining "edges" of the rectangle. M1 must be less than or equal to M2. So for the example of Figure 13, two groups of four numbers each are used to describe the location of the two rectangles. These numbers, read into the computer on two cards following the value of NLines, would be I-2,I-2,J-1,J followed by I-1,I+2,J,J+2. As a further example, the values of L1, L2, M1, and M2 for a single point of known potential where the 22nd axial line and the 44th radial line intersect would be: 22 22 44 44. Each set of four values L1, L2, M1, and M2 must be on a separate data card.

The above procedure is repeated for each region (which may or may not be a "connected" region) of distinct potential POT, with the order of input data being: POT, NLines, and NLines groups of L1, L2, M1, M2.

This concludes the input data development for FVSOLVR; a summary of the order in which the input data cards are read in the FVSOLVR program is given below.

```

READ NX,NY,NEPR,NEPZ,IFSKIP,IFBDY
Format 6I4

READ (HX(I), I=1,NX)
Format 10F8.0

READ (HY(J), J=1,NY)
Format 10F8.0

READ ((BDR(I,J), J=1, NEPR), I=1,NY-1)
Format 20I4

READ KO,KN,KK
Format 3I4

READ (EPSR(K), K=1,KK)
Format 16F5.0

READ ((BDZ(I,J), J=1,NEPZ), I=1,NX-1)
Format 20I4

READ KO,KN,KK
Format 3I4

READ (EPSZ(K), K=1,KK)
Format 16F5.0

```

This series of data cards is repeated, as required (see the discussion on dielectric sequences).

This series of data cards is repeated, as required (see the discussion on dielectric sequences).

The following five READ statements are executed only if IFBDY#0.

```

READ NGX,NGY
Format 2I4

READ (GH(I), I=1,NGX)
Format 8F10.3

READ (VG(I), I=1,NGX)
Format 8F10.3

READ (GH(J), J=1,NGY)
Format 8F10.3

READ (VG(J), J=1,NGY)
Format 8F10.3

READ NPOTS
Format I4

READ POT
Format F8.0

READ NLINES
Format I4

READ L1,L2,M1,M2
Format 4I4

```

Repeated NLINES Times

Repeated NPOTS Times

Checking Input Data

Once the data deck is set up, FVSOLVR can be executed, but it is advisable to check the data with three data check routines. This can save time and money by catching data errors before the solving routine is executed.

The first routine involves a boundary check program called BDYCHK. This program plots (using Calcomp plotting) dielectric boundaries in such a manner that a horizontal boundary appears as a horizontal line segment, at the given location, a vertical boundary line appears as a vertical line segment, and a diagonal boundary appears as two intersecting slashes forming an X. All diagonal boundaries appear in both the BDR(I,J) data and the BDZ(I,J) data. Therefore the appearance of only one slash of the X indicates an error in the BDR(I,J) and/or the BDZ(I,J) data, since one slash (\) of the X comes from the BDR(I,J) data and the other slash (/) of the X comes from the BDZ(I,J) data. An example of such a plot for the configuration of Figure 8 is shown in Figure 14. Numerical tables are also printed by the boundary check program to aid location of improper data.

The data deck set up for the boundary check program BDYCHK is as follows. The first card contains NX, NY, NEPR, and NEPZ. These integer variables are defined in the same way as in FVSOLVR. The second card contains IO, IN, JO, and JN. These data outline the region to be examined by the boundary check program. IO and IN are the indices of the axial grid lines and JO and JN are the indices of the radial grid lines that form the borders (or edges) of the region which the boundary check program is to examine. IO is less than IN and JO is less than JN. The HX(I) cards come next, followed by the HY(J) cards, the BDR(I,J) cards and, lastly, the BDZ(I,J) cards. The cards containing the HX(I), HY(J), BDR(I,J), and the BDZ(I,J) data are the exact same cards as those prepared for the FVSOLVR program. In summary, the deck set up is as follows.

```
READ NX,NY,NEPR,NEPZ
Format 4I4

READ IO,IN,JO,JN
Format 4I4

READ (HX(I), I=1,NX)
Format 10F8.0

READ (HY(J), J=1,NY)
Format 10F8.0

READ ((BDR(I,J), J=1,NEPR), I=1,NY-1)
Format 20I4

READ ((BDZ(I,J), J=1,NEPZ), I=1,NX-1)
Format 20I4
```

Once the boundary data are verified, a check of the dielectric constant information is performed. The given dielectric constants must be assigned within the boundaries. The name of the program which performs this check is EPSCHK. The EPSCHK program uses the boundary information, BDR(I,J), BDZ(I,J), and the dielectric constant assignment information, KO, KN, KK, and EPSR(KK) for the radial direction and KO, KN, KK and EPSZ(KK) for the axial direction, in order to generate (as printed output) two arrays of values of dielectric constants. One array contains the values of dielectric constants encountered in the radial direction search (rows), and the other array contains the values of dielectric constants encountered in the axial direction search (columns). Two tables are printed out, one for each array of dielectric constants. The two arrays are compared and inconsistencies between them are noted in the program output.

The data deck set up for the EPSCHK program is as follows. The first card contains NX, NY, NEPR, and NEPZ; this is the same as the NX, NY, NEPR, NEPZ card used in the boundary check program. The BDR(I,J) come next, followed by the KO, KN, KK, EPSR(KK) cards, set up in the same way as shown in the FVSOLVR program. Finally, the BDZ(I,J) cards and accompanying KO, KN, KK, EPSZ(KK) cards are read. A summary of the order of reading data in the EPSCHK program is as follows.

```
READ NX,NY,NEPR,NEPZ
Format 4I4

READ ((BDR(I,J), J=1,NEPR), I=1,NY-1)
Format 20I4

READ KO,KN,KK
Format 3I4
READ (EPSR(K), K=1,KK) ] Repeated, as required.

Format 16F5.0

READ ((BDZ(I,J), J=1,NEPZ), I=1,NX-1)
Format 20I4

READ KO,KN,KK
Format 3I4
READ (EPSZ(K), K=1,KK) ] Repeated, as required.

Format 16F5.0
```

A third data check is used to verify the values and locations of known input potentials. This check involves the use of FVSOLVR itself. The check is implemented by simply using the data deck to be used with the actual program, except with IFSKIP#0 in the NX, NY, NEPR, NEPZ, IFSKIP, IFBDY card. This results in FVSOLVR skipping execution of the solving algorithm and printing out all known potentials at their given grid locations and "-1" at all other grid locations

Output From FVSOLVR

Potentials are printed by a line printer as well as written on tape; therefore the user must supply the tape. Of course, if the user wishes to change the output statements in the program, the output may be obtained in any form. The array $V(I,J)$ contains the potential solution at the nodes having coordinates $(HX(I),HY(J))$.

Potential listings for FVSOLVR are printed out in the following manner. Blocks of 50 values of potential in the axial direction and 14 values in the radial direction, maximum, are printed on each page of output from the computer. The table is started from the lower left hand corner of the solution region and proceeds to the right producing blocks of 14×50 potential values. This is illustrated in Figure 15. If, for example, as in "page 3" in Figure 15, fewer than 14 values of potential are needed to complete the printing of the data in the radial direction, then the printout will fill only a portion of the page. A similar procedure is followed in the axial direction, until the entire solution region is printed.

USE OF THE PLOT PROGRAM FVPLOT

Use of the plotter program FVPLOT will now be described. The plotter can be set up to plot equipotential and/or flux lines. However, as a result of the inherent nature of the plotting program, flux lines can be plotted only for problems of the "point gap" type. Examples of "point gap" problems are shown in Figure 16. Plotting flux lines in configurations other than the "point gap" type may cause difficulties. Equipotential lines can always be plotted, irrespective of whether or not the problem is of a "point gap" nature.

Data for FVPLOT may be input from cards or tape. The user must use the appropriate "read" statements. The first information read is IVU. If $IVU=1$, the program plots only the potential lines. If $IVU=2$, the program plots only the field lines. If $IVU=3$, the program plots both potential and field lines. (If flux lines are to be plotted, FVSOLVR must be executed to solve for the necessary field values. For details, see CEL Technical Note N-1502.)

Next, a card containing IO, IN, JO, JN, NQUAD, KK, VMIN, and SZ is read. IO and IN are the first and last indices, respectively, of the axial grid lines that form edges of the region to be plotted. JO and JN are the first and last indices, respectively, of the radial grid lines that form edges of the region to be plotted. NQUAD indicates whether only the solution region solved for by FVSOLVR is to be plotted or whether "mirror images" of this solution region are also to be plotted, as is illustrated in Figure 17. If $NQUAD=1$, only the solution region obtained from FVSOLVR is plotted; if $NQUAD=2$, one mirror reflection is introduced; if $NQUAD=4$, two mirror reflections are introduced. This feature enables problems of varying degrees of symmetry to be solved by

FVSOLVR and then plotted in their entirety by FVPLOT while not necessarily inputting the full geometrical configuration as data to either program. KK is the number of equipotential lines to be plotted "automatically" by FVPLOT. SZ is the voltage increment between successive equipotential lines and VMIN is the potential value which is incremented by SZ to determine the first equipotential line to be plotted. Successive increments of SZ are added and an equipotential line is plotted for each of the KK potential values. The first potential value plotted is VMIN + SZ and the last value plotted is VMIN + (KK x SZ). The value VMIN is not plotted because it is assumed that VMIN usually represents an electrode or a boundary of the solution region. Likewise, any known voltages, such as electrodes, should not be plotted "automatically" as just described. These voltages should be given as separate input data to FVGRPHR, which will be explained later. As an example, if two electrodes of known potential are 0.0 and 100.0 volts and equipotential lines are desired at 10.0 volt intervals, then KK=9, VMIN=0.0, and SZ=10.0. The 0.0 and 100.0 volt lines are not plotted "automatically" and are not counted when determining KK.

NX and NY are read next. NX is the number of axial grid lines and NY is the number of radial grid lines used in the FVSOLVR solution. Following this, the HX(I) and HY(J) data are read in the order HX(1), HX(2), HX(3), ..., HX(NX), HY(1), HY(2), HY(3), ... HY(NY). Then the voltages V(I,J), previously calculated (by FVSOLVR) at the grid points, are read as input to FVPLOT. The NX, NY, HX(I), HY(J), and V(I,J) data can be stored on tape directly from the FVSOLVR solution and read from the same tape into FVPLOT.

If IVU \neq 1, separate data must be input for the field (flux lines) plot. If IVU=1, the separate field data is to be omitted. The field data are MX and MY (which are exactly analogous to the number of grid lines, NX and NY, in the equipotential case), GX(I), GY(J), and U(I,J) (which are exactly analogous to HX(I), HY(J), and V(I,J) for the equipotential case). This information can also be stored on tape from the FVSOLVR solution and read from the same tape as input to FVPLOT.

The last information inputted is that of various reference lines into the plot. Such lines may include known potential lines (as previously mentioned), dielectric boundaries, or any other lines that the user wishes to plot. Data needed to plot known potential or reference lines is as follows. NLINES is the number of lines drawn by the plotter to generate all figures and lines. In determining the numerical value of NLINES, a distinct line is counted each time the pen is lifted off the paper. NPTS, which is read next, is the number of points needed to generate a given line. For each line that is to be plotted, a data card containing a value for NPTS is followed by a card (or cards) containing values of LX(N) and LY(N), with the LX(N) and LY(N) data appearing on the cards in the order LX(1), LY(1), LX(2), LY(2), LX(3), LY(3), ..., LX(NPTS), LY(NPTS). NPTS is the number of points being used to generate the particular line, and LX(N) and LY(N) are the indices of the axial and radial grid lines, respectively, which intersect at point N. The

plotter draws straight lines between these points. If a long straight line is to be drawn, only the end points of the line need be given. Each time the line turns a new point is needed.

The following is a short review of the order in which the input data cards are read in the FVPLOT program. Each READ statement by which data are read most conveniently from tapes is indicated by an asterisk.

```
READ IVU
Format I4

READ IO,IN,JO,JN,NQUAD,KK,VMIN,SZ
Format 6I4, 2F5.0

*READ NX,NY
Format 2I4

*READ (HX(I), I=1, NX), (HY(J), J=1, NY)
Format 8F10.3

*READ ((V(I,J), I=1,NX), J=1, NY)
Format 8F10.3
```

The previous five READ statements are executed irrespective of the value assigned to the integer variable IVU. The following three READ statements are executed only if IVU=2 or IVU=3.

```
*READ MX,MY
Format 2I4

*READ (GX(I), I=1,MX), (GY(J), J=1,MY)
Format 8F10.3

*READ ((U(I,J), I=1,MX), J=1,MY)
Format 8F10.3

READ NLINES
Format I4

READ NPTS
Format I4

READ (LX(N), LY(N), N=1,NPTS)      Repeat NLINES times
Format 20I4
```

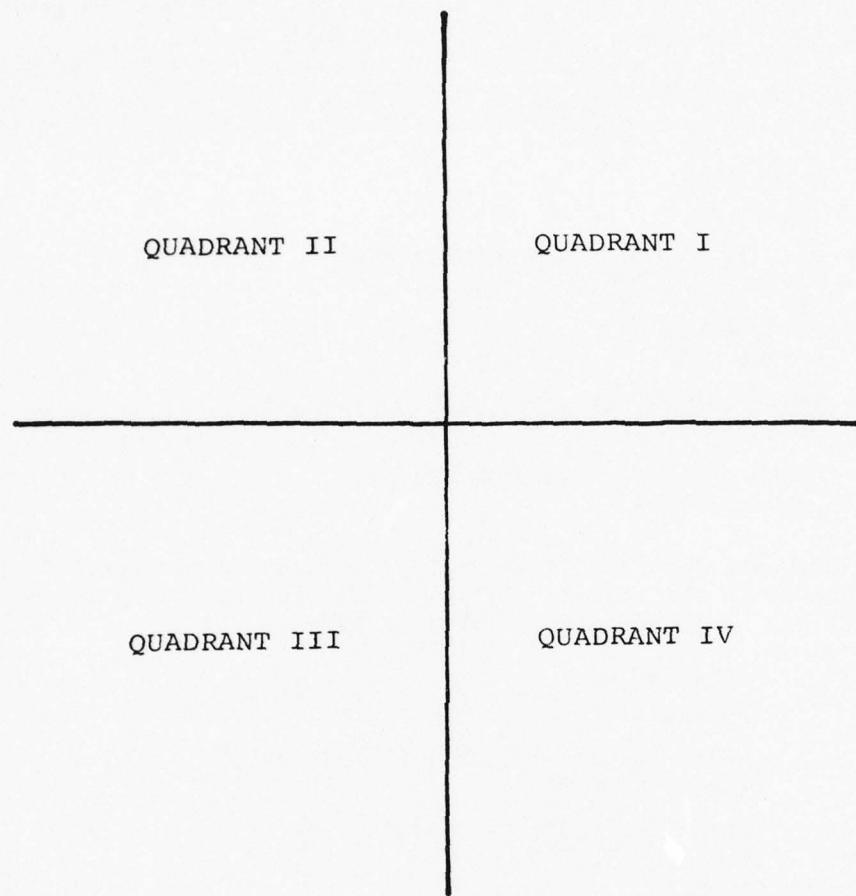


Figure 1. Labeling of quadrants in the cartesian coordinate system.

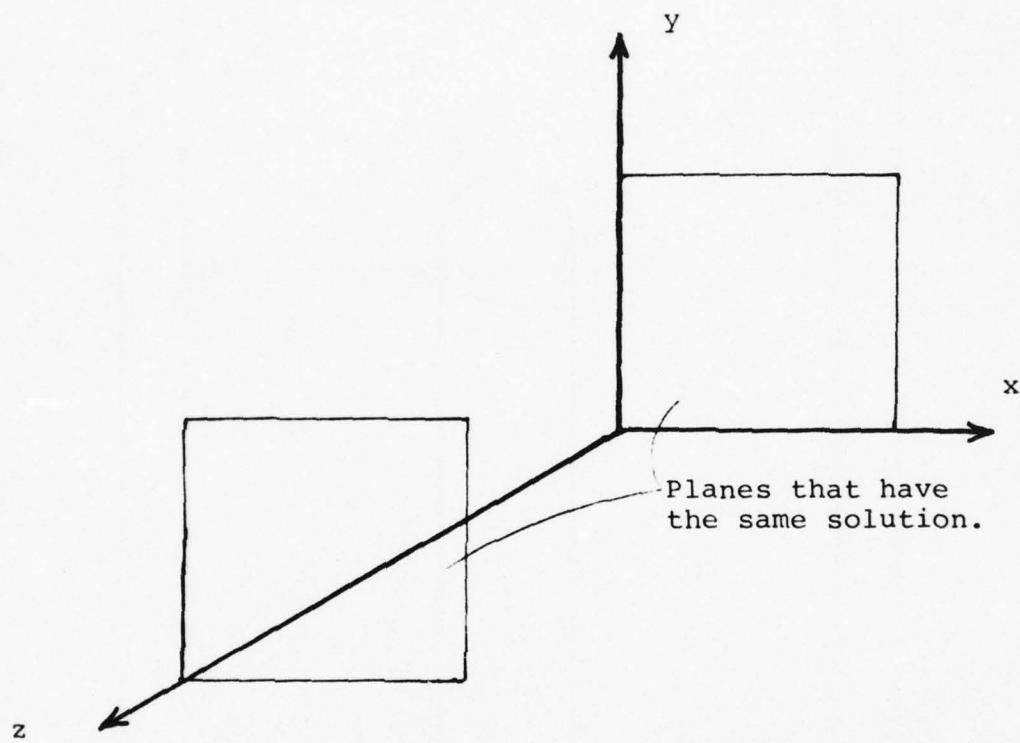
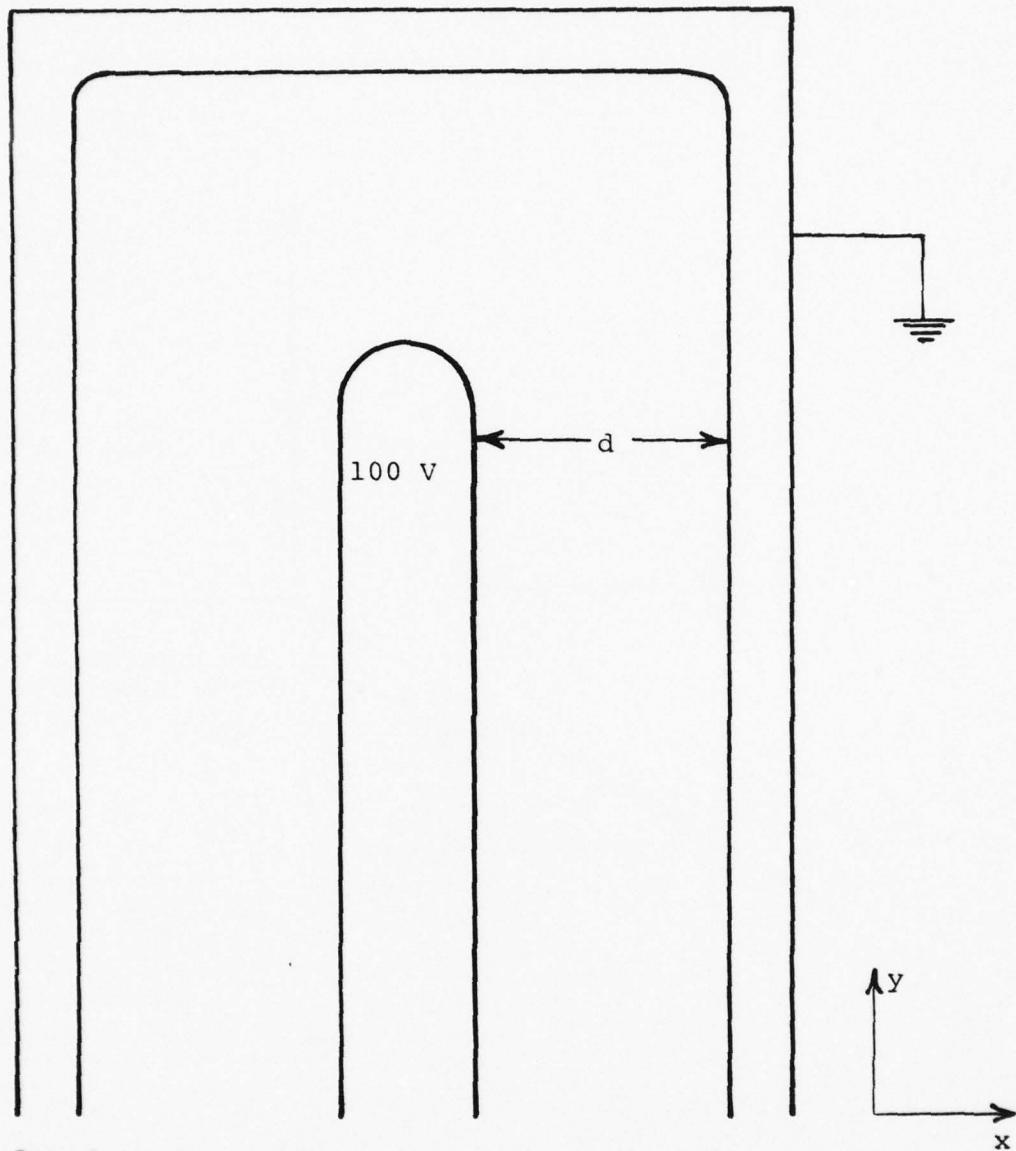


Figure 2. Illustration of two planes having identical solutions in the case of the cartesian coordinate system



Capacitor plate within a housing. The geometry of the capacitor and the field solution is the same in any plane perpendicular to the z-axis (the z-axis is perpendicular to the plane of the paper).

Figure 3. Example of a problem described in a cartesian coordinate system.

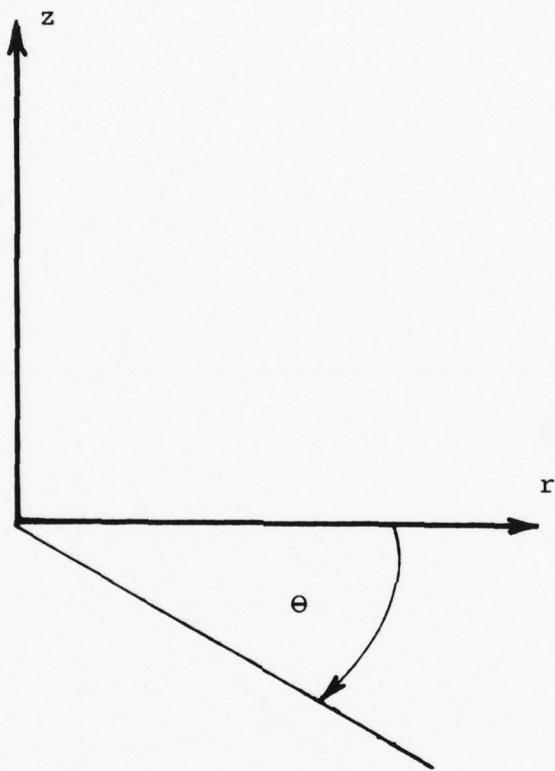


Figure 4. Coordinates used in the cylindrical system.

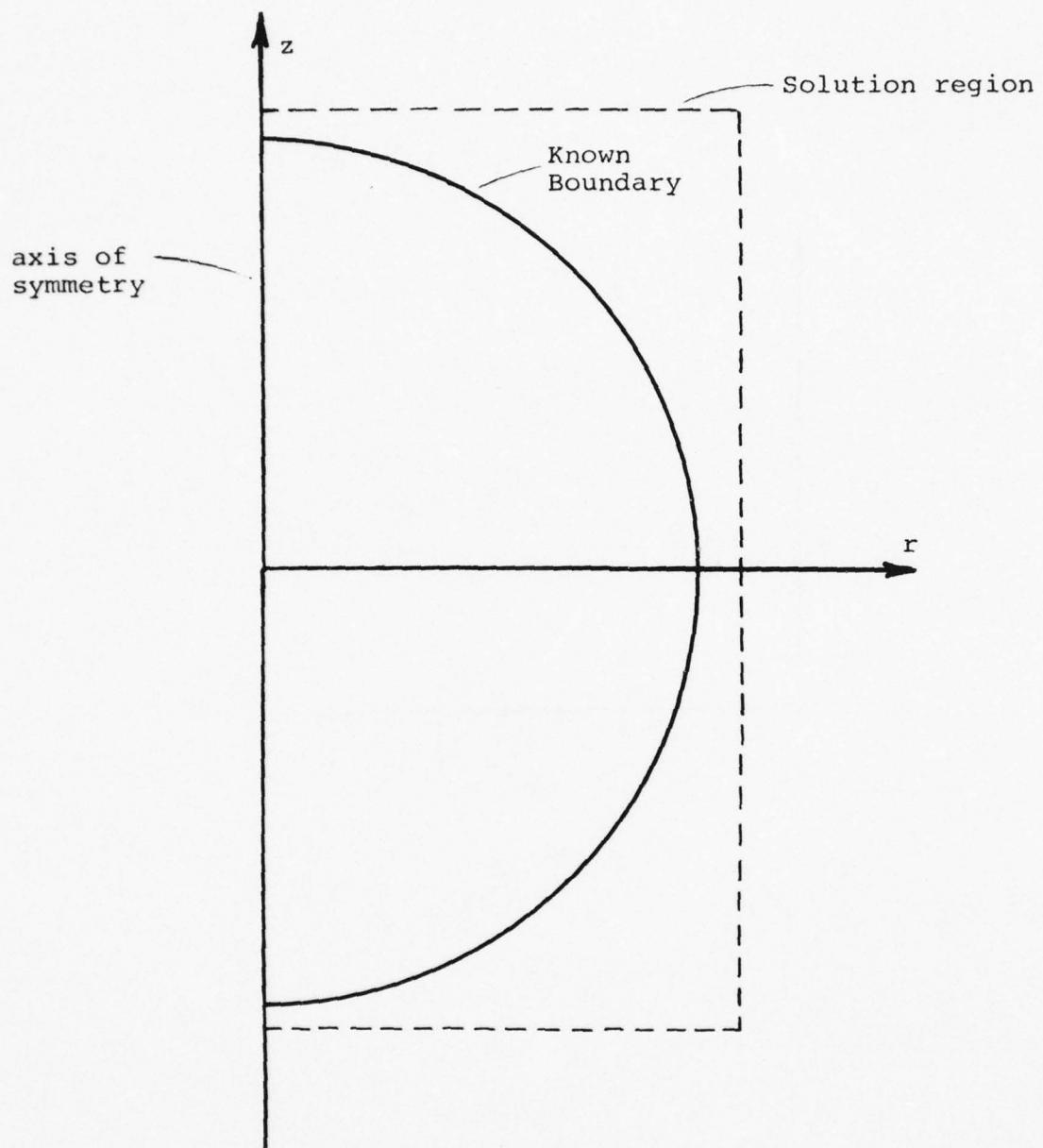


Figure 5. Illustration of a case of a circular known boundary within the solution region in the cylindrical system.

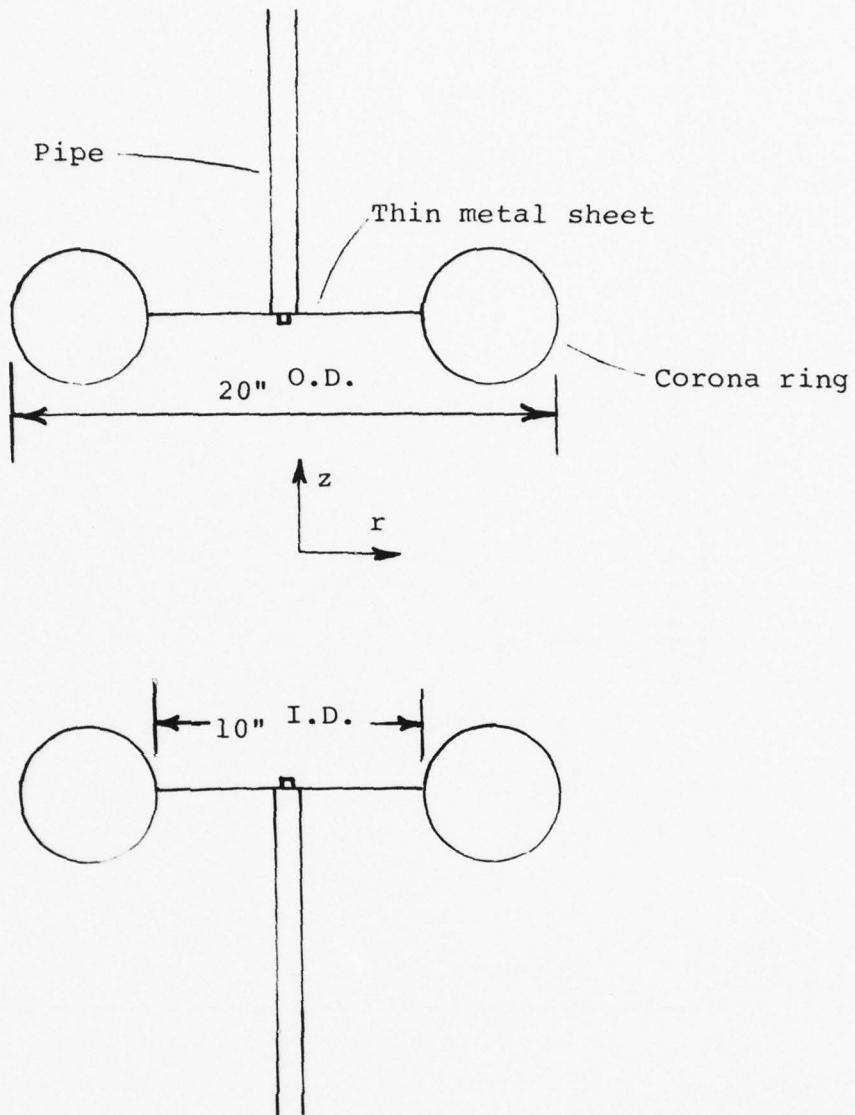


Figure 6. Geometry of corona rings suspended by pipes.

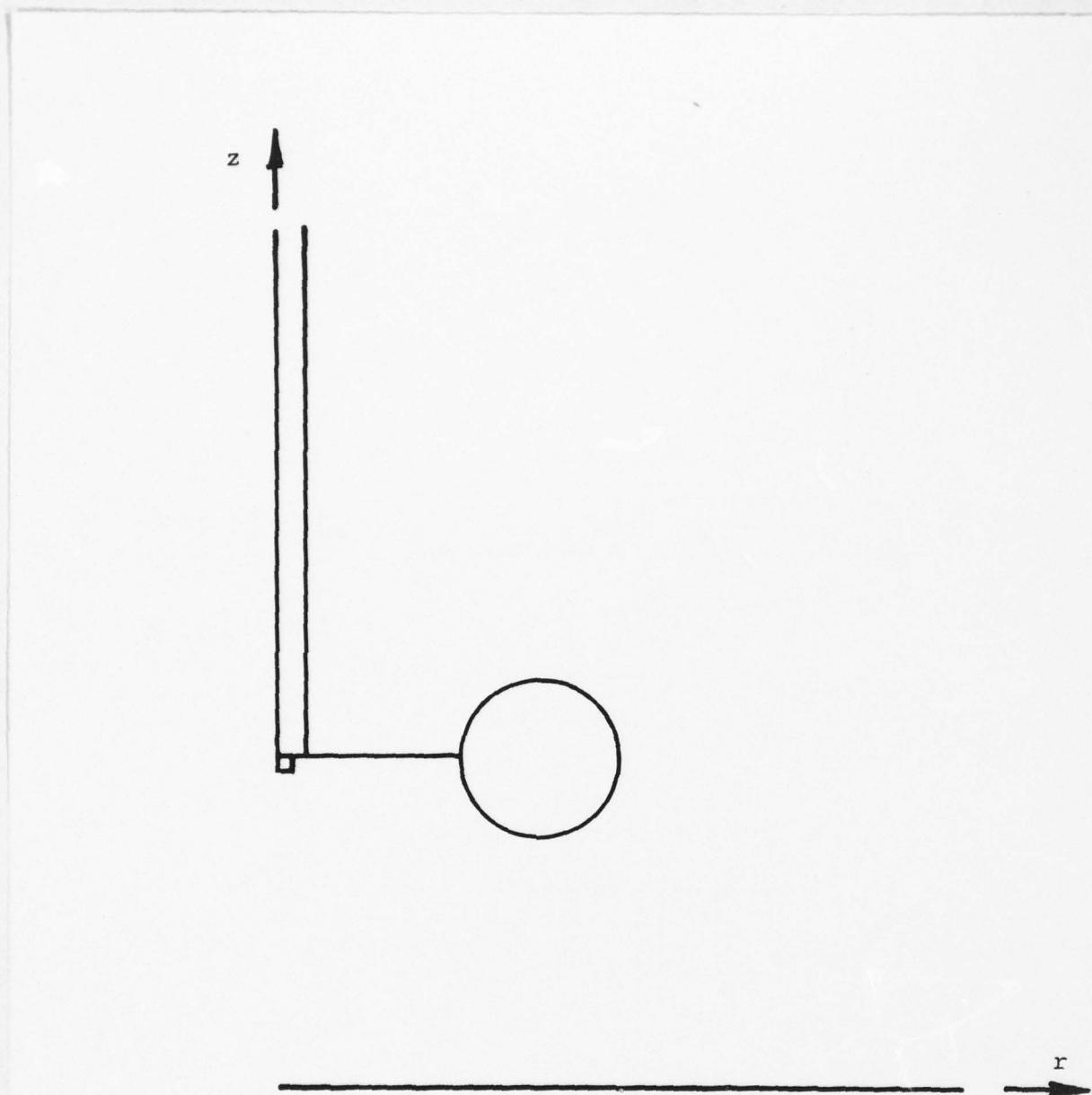


Figure 7. The reduced solution region for the corona rings shown in Figure 6 after taking symmetry into account.

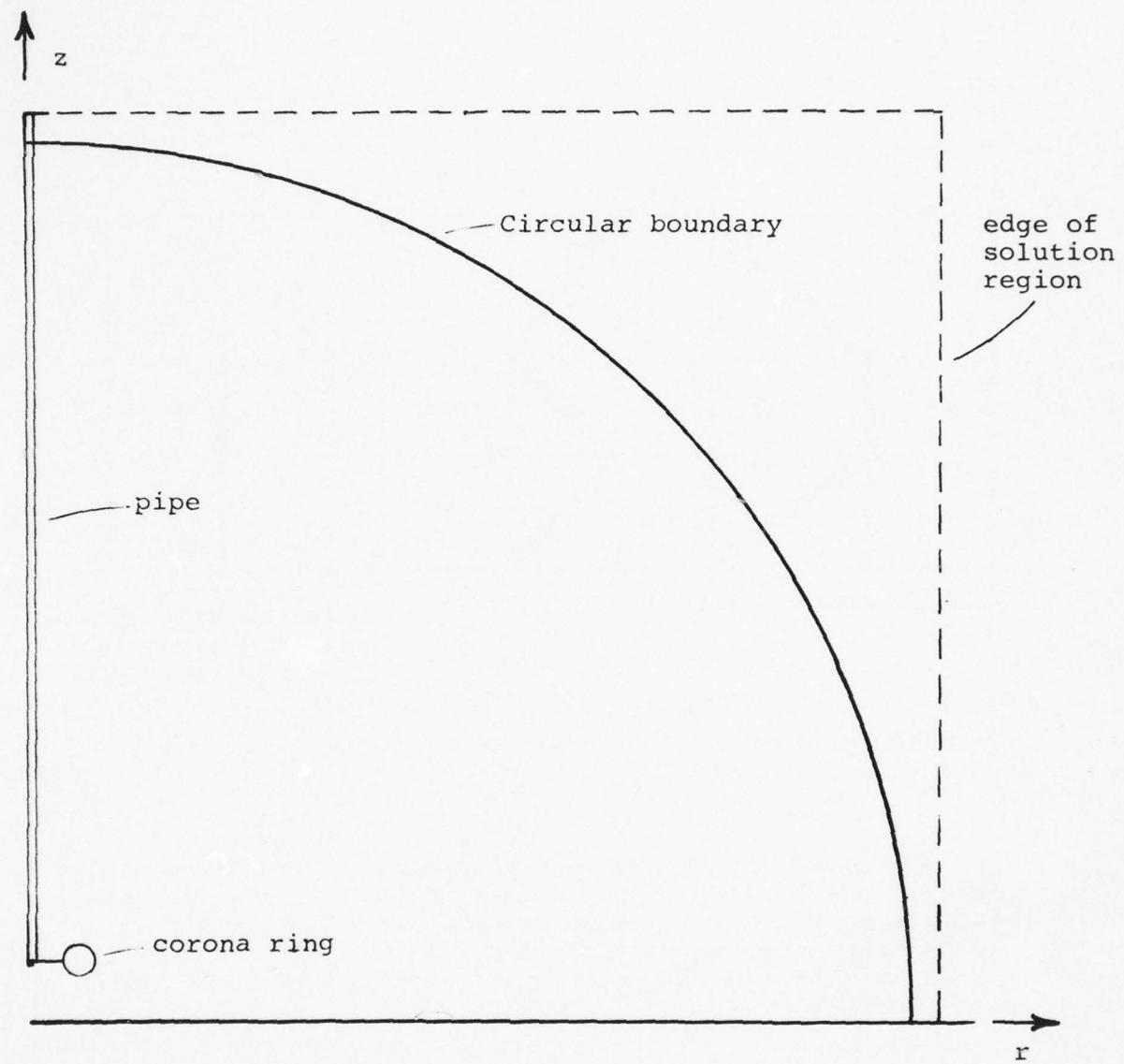
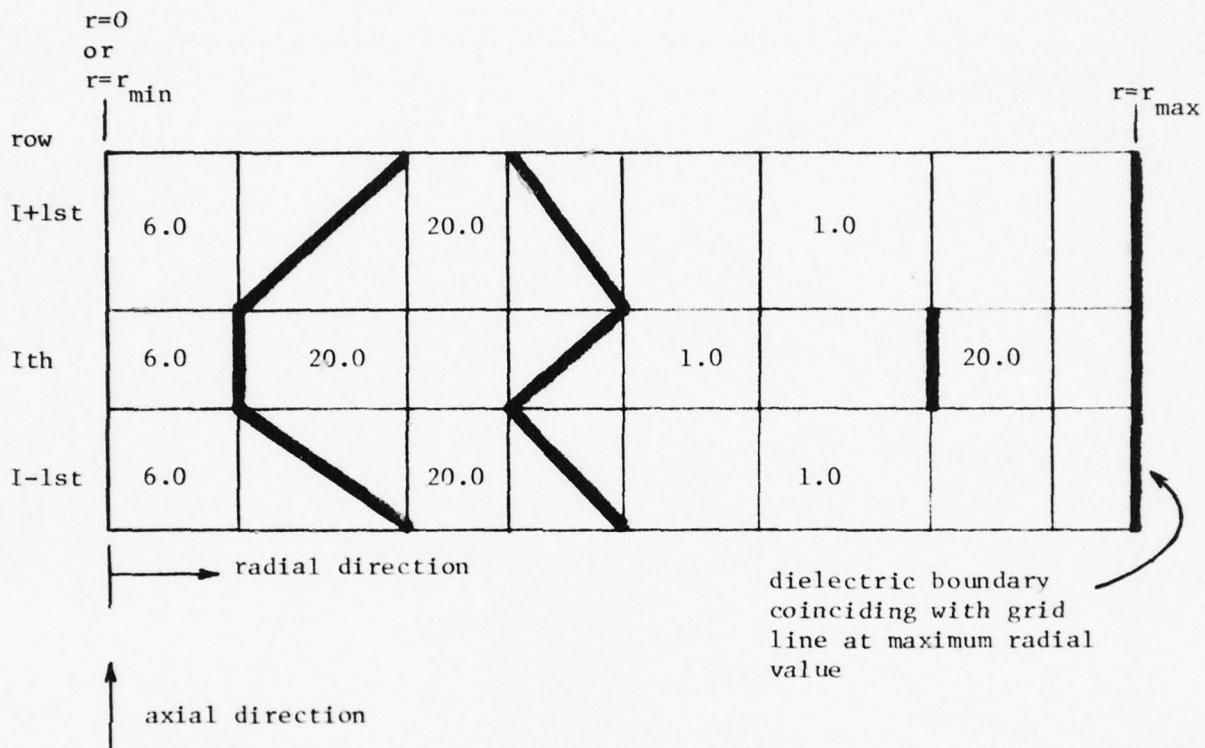
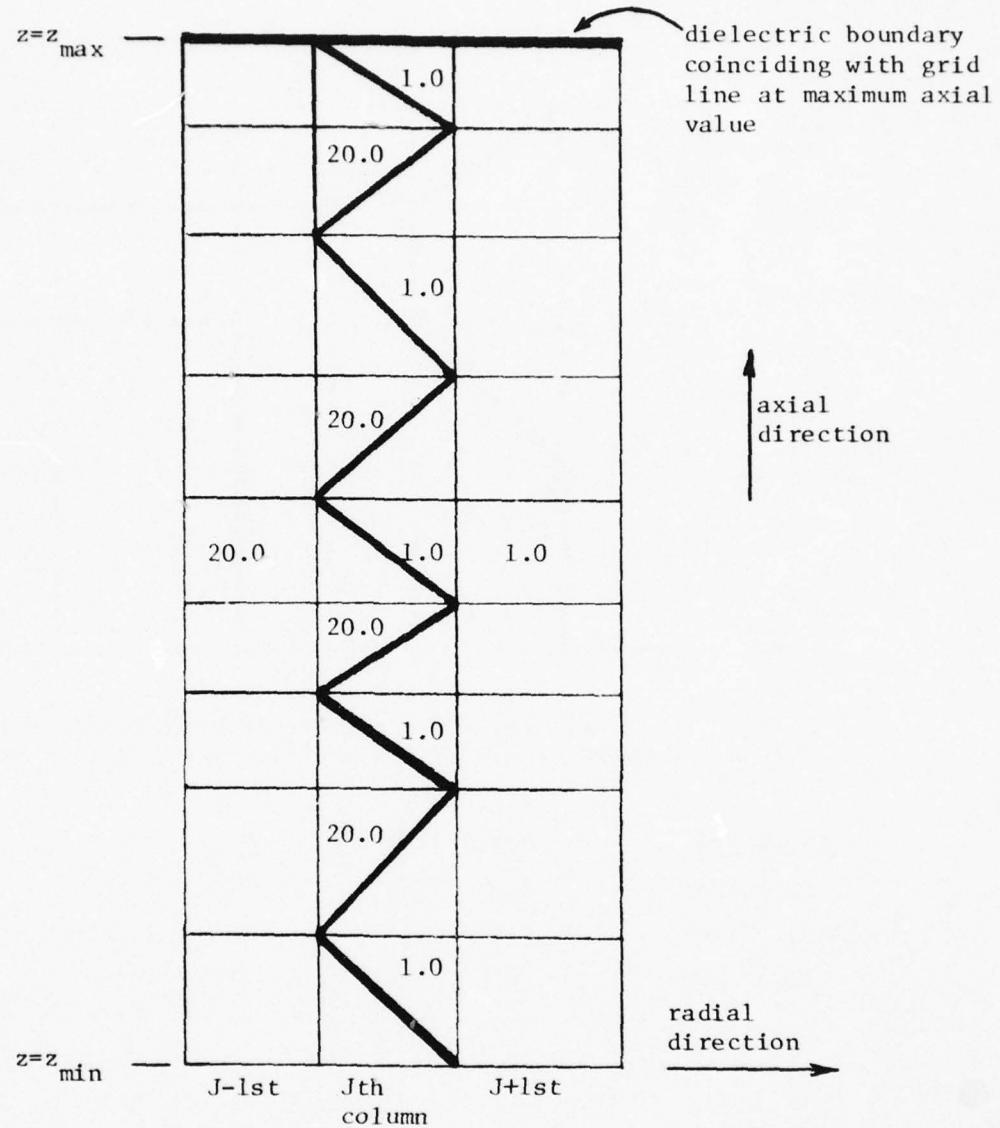


Figure 8. Reduced solution region with circular boundary



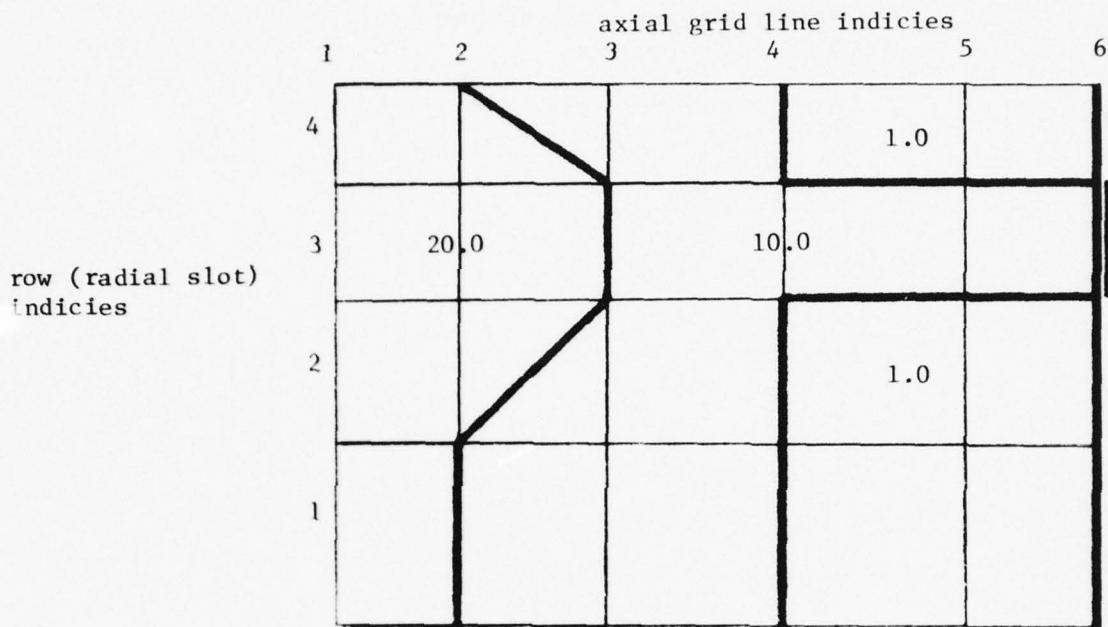
Dielectric boundaries are shown as heavy lines. The numbers in the grid are relative dielectric constants. That is, in the I th row, the relative dielectric constant changes from 6.0 to 20.0 to 1.0 to 20.0 in passing outward from the axis of symmetry in the radial direction. There must be a dielectric boundary on the grid line of maximum radial value.

Figure 9. Examples of dielectric boundaries encountered in the radial direction.



Dielectric boundaries are shown as heavy lines. The numbers in the grid are relative dielectric constants. That is, in the Jth column, the relative dielectric constant changes from 20.0 to 1.0 to 20.0 to ... 1.0 to 20.0 to 1.0 in going from bottom to top in the axial direction. There must be a dielectric boundary on the grid line of maximum axial value.

Figure 10. Examples of dielectric boundaries encountered in the axial direction.



The heavy lines are dielectric boundaries; and the numbers in the grid are dielectric constant values.

$$BDR(1,1)=4$$

$$BDR(1,2)=8$$

$$BDR(1,3)=12$$

$$BDR(2,1)=5$$

$$BDR(2,2)=8$$

$$BDR(2,3)=12$$

$$BDR(3,1)=6$$

$$BDR(3,2)=12$$

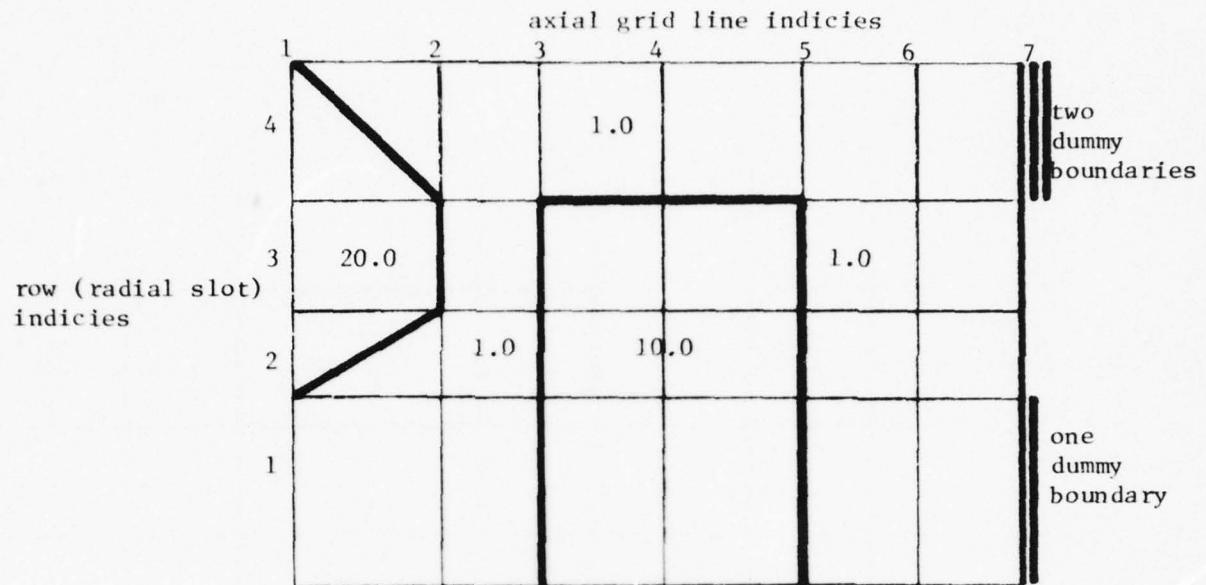
$$BDR(3,3)=12$$

$$BDR(4,1)=5$$

$$BDR(4,2)=8$$

$$BDR(4,3)=12$$

Figure 11. Numbering scheme used in the assignment of the BDR (I,J) values where radially encountered dielectric boundaries are specified.



The heavy lines are dielectric boundaries; and the numbers in the grid are dielectric constant values

$$\begin{array}{llll}
 \text{BDR}(1,1)=6 & \text{BDR}(1,2)=10 & \text{BDR}(1,3)=14 & \text{BDR}(1,4)=14 \\
 \text{BDR}(2,1)=3 & \text{BDR}(2,2)=6 & \text{BDR}(2,3)=10 & \text{BDR}(2,4)=14 \\
 \text{BDR}(3,1)=4 & \text{BDR}(3,2)=6 & \text{BDR}(3,3)=10 & \text{BDR}(3,4)=14 \\
 \text{BDR}(4,1)=3 & \text{BDR}(4,2)=14 & \text{BDR}(4,3)=14 & \text{BDR}(4,4)=14
 \end{array}$$

Figure 12. Example of the use of several dummy boundaries at the last axial grid line to complete the $\text{BDR}(I,J)$ array.

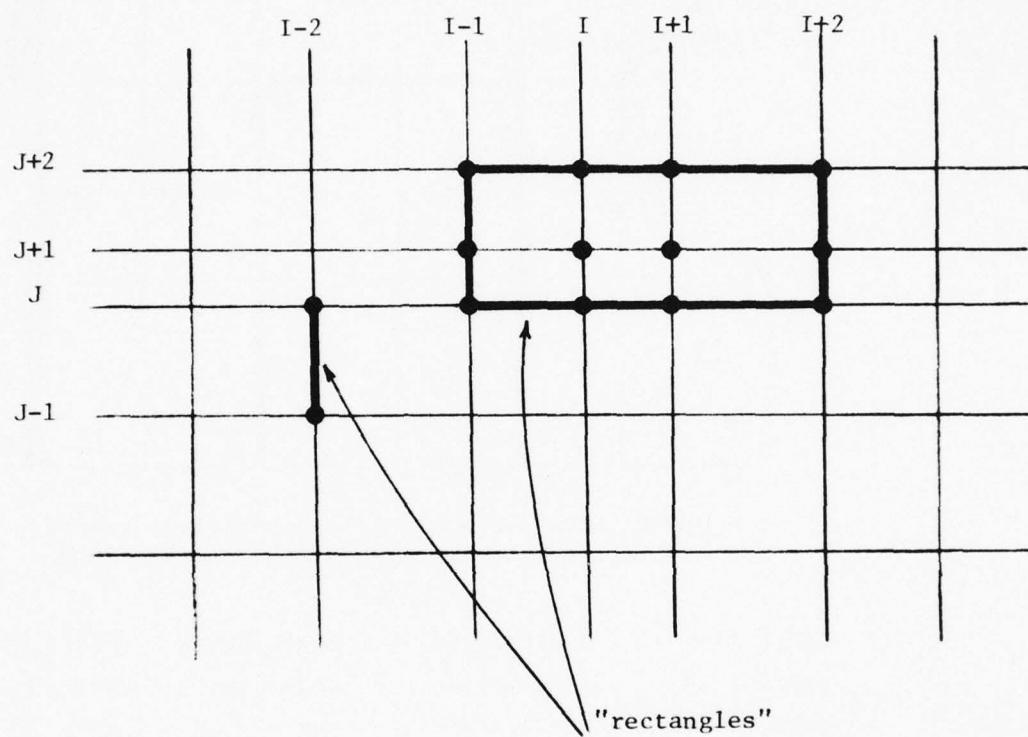


Figure 13. A region of known potential "POT" which is described by two "rectangles".

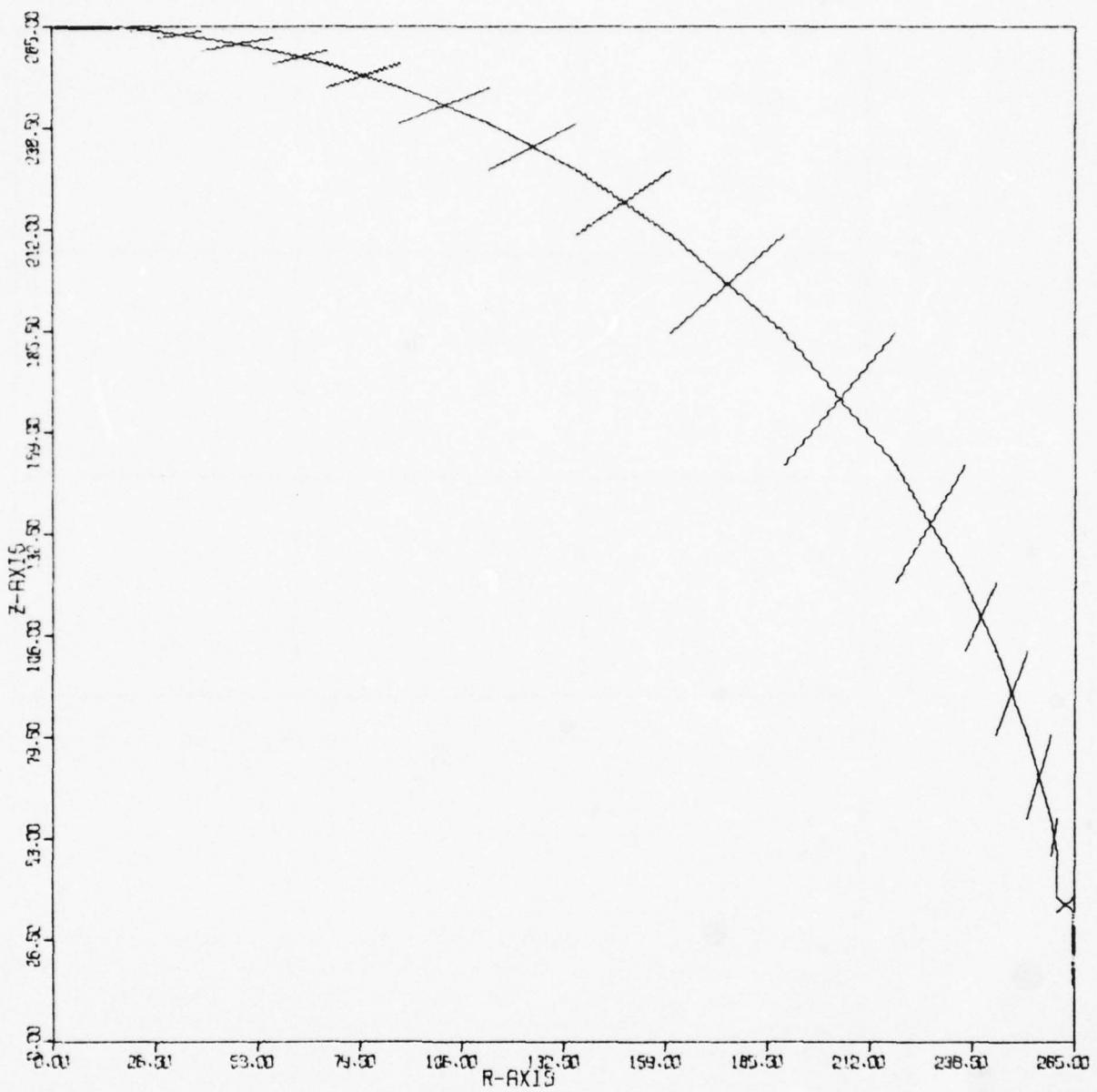
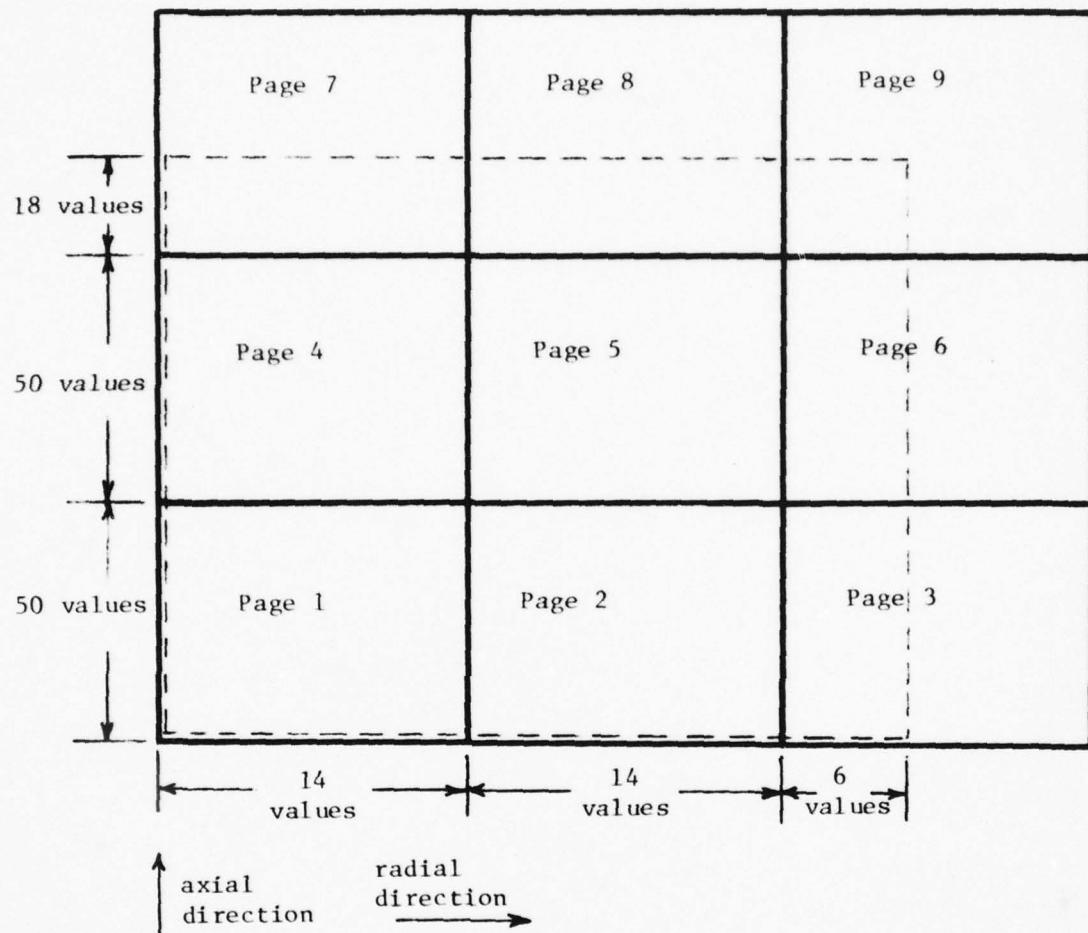


Figure 14. An example of a plot from BDYCHK, the boundary check program, for the configuration of Figure 8.



In this example $NX=34$ and $NY=118$. There exists correspondence between the position of data in the printout and the location in the solution region. The solution region is indicated by a dashed line in this figure. In this particular case nine pages of computer printed output are required.

Figure 15. Example of the format of the printout of field values from FVSOLVR.

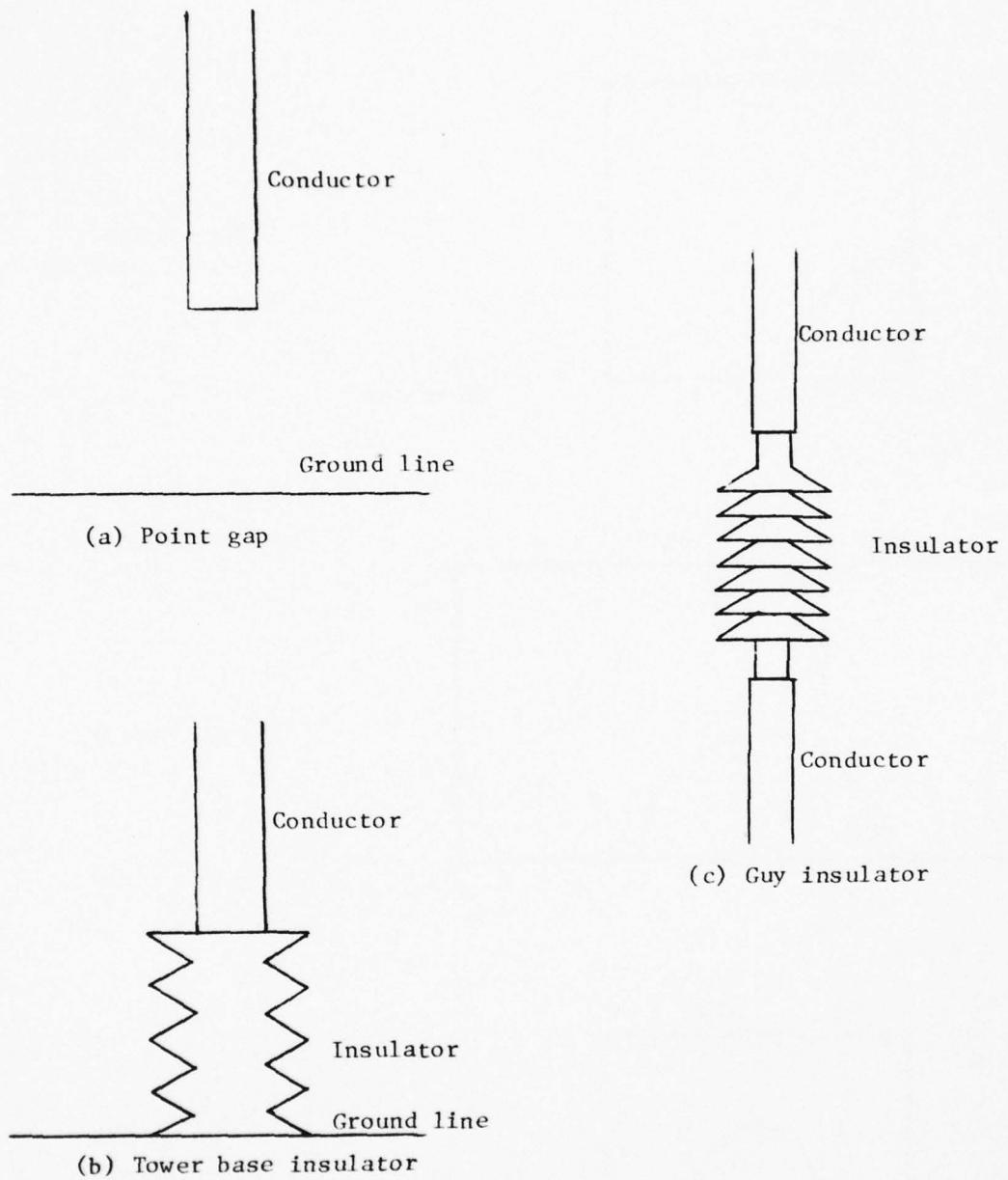
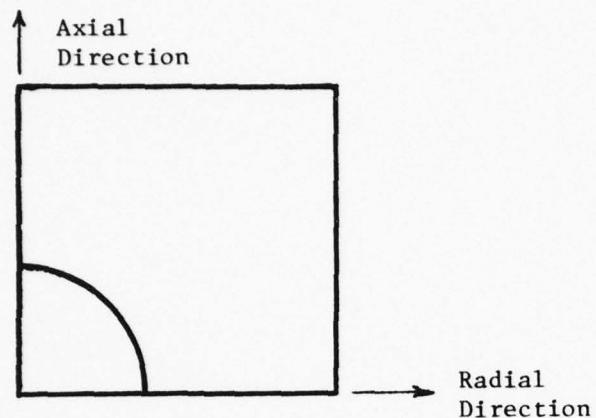
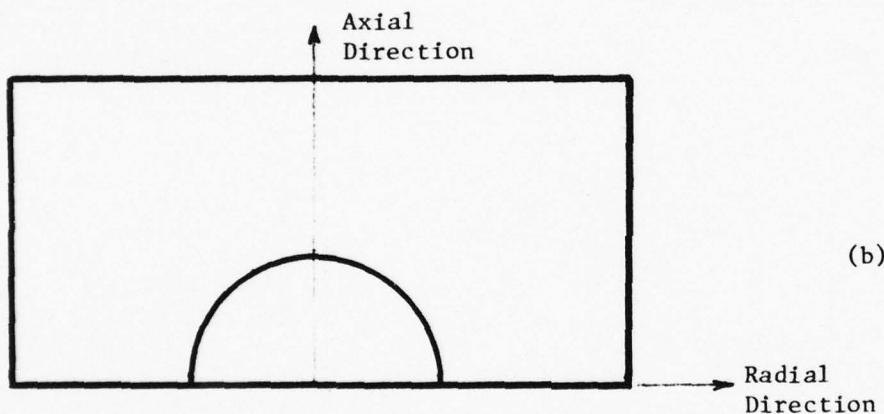


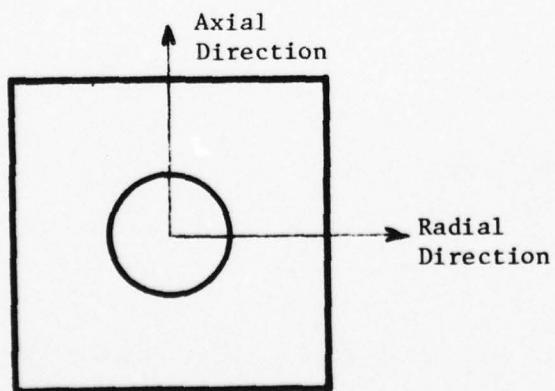
Figure 16. Examples of problems of a point gap nature.



(a) NQUAD=1
1 Quadrant Plotted



(b) NQUAD=2
2 Quadrants Plotted



(c) NQUAD=4
4 Quadrants Plotted

Figure 17. Illustration of the effect of the NQUAD assignment statement.

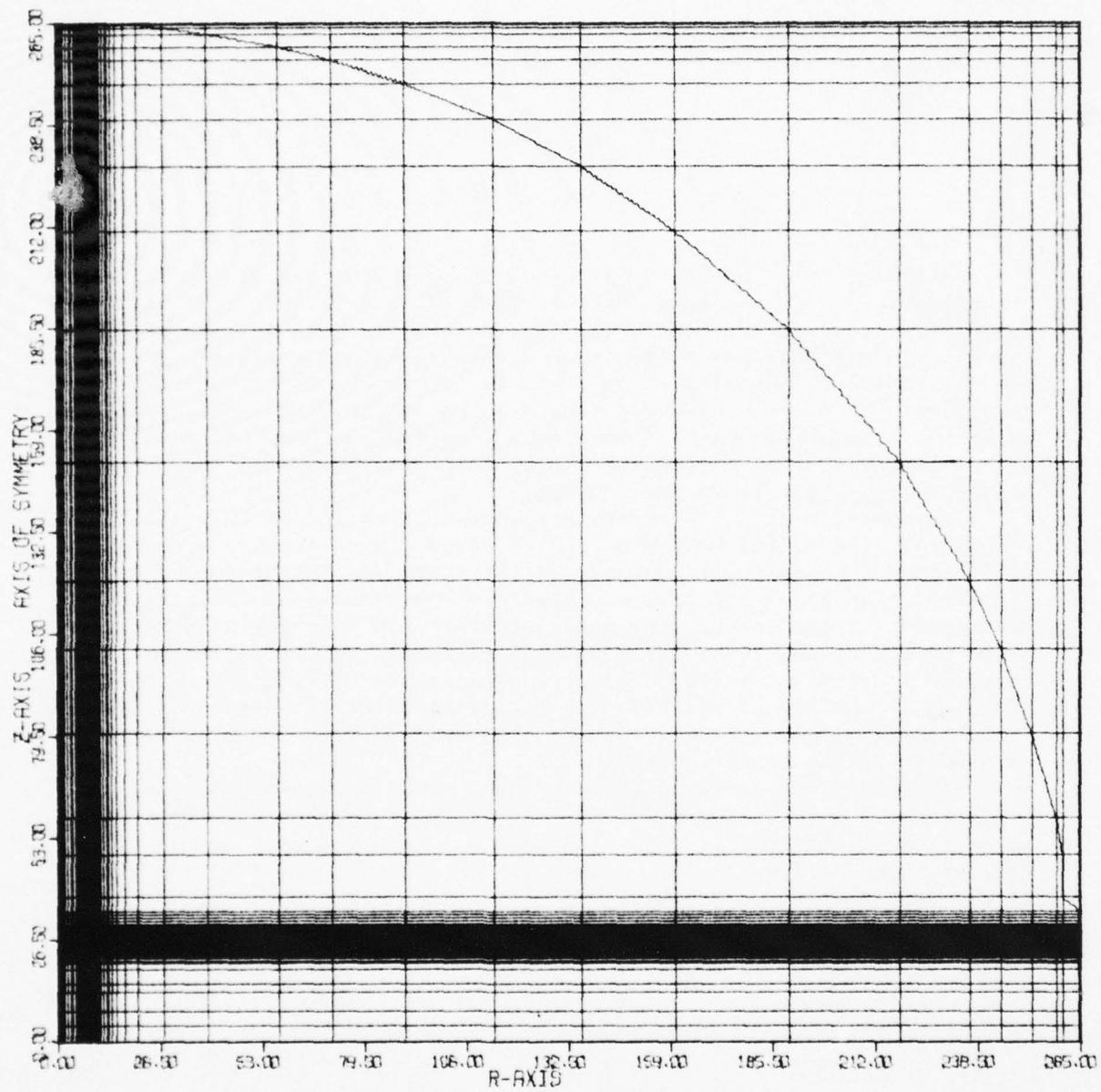
Appendix A

EXAMPLE PROBLEM

An example of a potential distribution problem is given to illustrate the organization of the input data for FVSOLVR and FVPLOT. This simple problem, which is described in the text and illustrated in Figures 6, 7, and 8, involves only two dielectrics and two given potentials. One of the dielectric values is zero and is used only to satisfy boundary conditions near the top and right-hand edges of the grid. Many problems which are commonly encountered are more complicated than this example, and will require a more elaborate input data set. However, the data format will be just as in this example.

The corona ring and pipe are assigned a potential of 100 volts. The radial line at the bottom of the solution region (plane of symmetry) is assigned a potential of 0 (zero) volts. The region inside the circular boundary is assigned a relative dielectric constant of 1. This includes the regions of the corona ring and pipe which can have any arbitrary dielectric constant since the potential in those regions is known. The value of 1 is chosen for convenience. The region outside the circular boundary is assigned a relative dielectric constant of 0 (zero). Thus it is not necessary to assign boundary potentials to the top and right-hand edges of the solution region.

The grid lines in the solution region are shown in Figures A-1 and A-2. Table A-1 lists the input data for FVSOLVR. Table A-2 lists the input data for FVPLOT for the equipotential line plot near the corona ring as shown in Figure A-3. Figure A-4 is an equipotential line plot of the entire solution region.



The grid lines near the corona ring are too densely packed to allow good resolution in this figure. Figure A-2 illustrates the grid lines near the corona ring.

Figure A-1. Grid lines for the entire solution region for the corona ring problem shown in Figure 8.

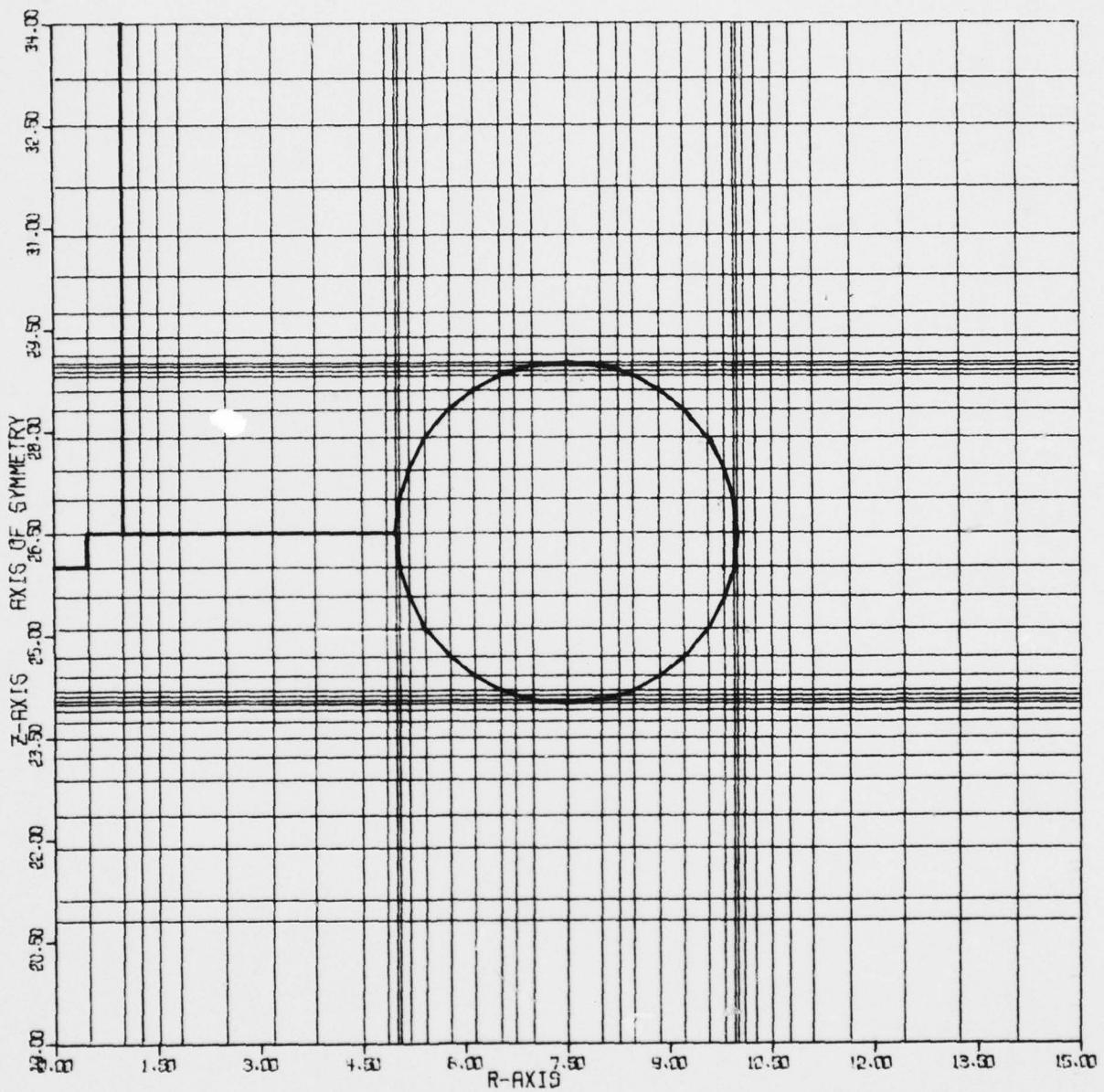


Figure A-2. Illustration of the grid lines in the neighborhood of the corona ring.



Figure A-3. Plot of equipotential lines in the neighborhood of the corona ring.

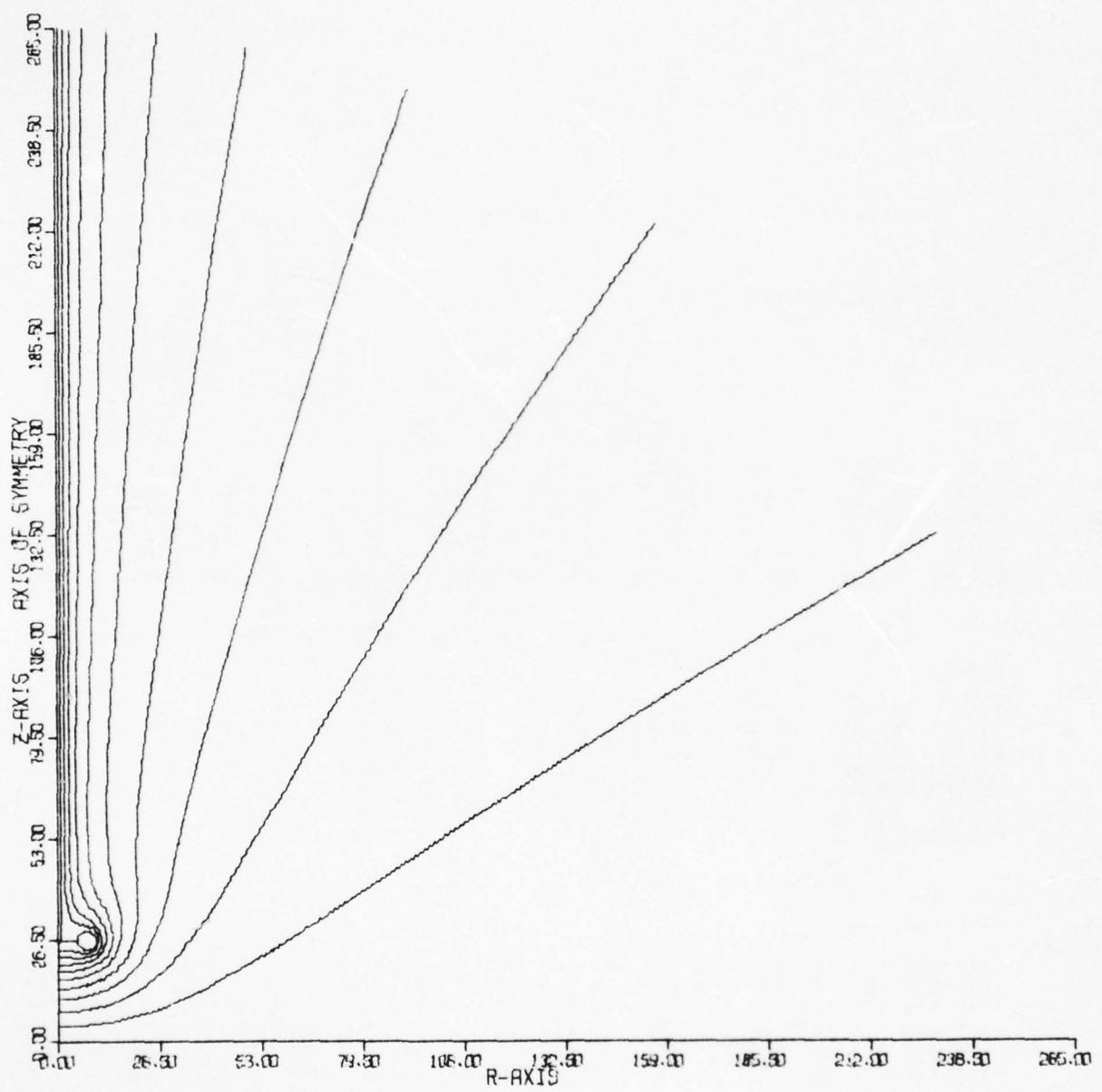


Figure A-4. Plot of equipotential lines for the entire solution region of the corona ring problem.

TABLE A-1. INPUT DATA FOR FVSOLVR

NX, NY, NEPZ, IFSKIP, IF80Y

60 61 2 2 0 0

HX(I)

0.00	0.50	1.00	1.27	1.53	1.84	2.51	3.18	3.80	4.50
4.85	5.00	5.051	5.179	5.429	5.776	6.144	6.520	6.735	7.003
7.500	7.997	8.265	8.480	8.856	9.224	9.571	9.821	9.949	10.00
10.09	10.26	10.49	10.76	11.09	11.64	12.42	13.23	14.08	15.00
17.20	20.70	27.30	38.60	57.00	71.10	90.20	113.00	135.70	160.40
189.50	218.10	236.30	244.50	252.50	258.50	260.50	264.58	264.85	265.00

HY(J)

0.00	4.00	8.00	13.00	15.00	19.00	20.80	21.12	21.87	22.35
22.89	23.21	23.50	23.75	23.90	24.00	24.05	24.12	24.20	24.40
24.69	25.10	25.57	26.00	26.50	27.00	27.43	27.90	28.31	28.60
28.80	28.48	28.95	29.00	29.12	29.38	29.74	30.28	30.89	31.59
32.50	33.20	34.00	35.00	48.63	58.33	80.43	102.20	119.95	150.52
185.24	210.94	227.62	239.70	249.18	255.28	258.80	262.17	263.60	264.50
265.00									

BDR(I,J)

118	120	118	120	118	120	118	120	117	120	116	120	116	120	116	120	116	120
116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120
116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120
116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120
116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120	116	120
116	120	116	120	115	120	114	120	113	120	111	120	109	120	107	120	105	120
101	120	99	120	97	120	95	120	93	120	91	120	89	120	87	120	85	120

KO, KN, KK

1 59 2

ESPR(KK)

1.0 0.0

TABLE A-1. (cont.)

KD, KN, KK

60 60 1

ESPR(KK)

0.0

80Z(I,J)

120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122
120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122
120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122
120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122
120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122	120	122
120	122	119	122	117	122	115	122	113	122	111	122	109	122	107	122	105	122	103	122	101	122	99	122
101	122	99	122	97	122	95	122	93	122	91	122	87	122	81	122	77	122	73	122	69	122	65	122

KD, KN, KK

1 58 2

ESPZ(KK)

1.0 0.0

KD, KN, KK

59 59 1

ESPZ(KK)

0.0

NPUTS

2

TABLE A-1. (cont.)

POT

0.0

NLINES

1

L1, L2, M1, M2

1 60 1 1

PUT

100.

NLINES

21

L1, L2, M1, M2

1	2	24	61
3	3	25	61
4	12	25	25
13	13	24	26
14	14	23	27
15	15	22	28
16	16	21	29
17	17	20	30
18	18	19	31
19	19	18	32
20	20	17	33
21	21	16	34
22	22	17	33
23	23	18	32
24	24	19	31
25	25	20	30
26	26	21	29
27	27	22	28
28	28	23	27
29	29	24	26
30	30	25	25

TABLE A-2. INPUT DATA FOR FVPLT FOR FIGURE A-3

IVU

1

IO, IN, JO, JN, NQUAD, KK, VMIN, SZ

1 44 1 45 1 9 0.0 10.0

NX, NY

(DATA ON TAPE FROM FVSOLVR)

MX(I), MY(J)

(DATA ON TAPE FROM FVSOLVR)

V(I,J)

(DATA ON TAPE FROM FVSOLVR)

NLINES

3

NPTS

2

LX(N), LY(N)

1 1 44 1

TABLE A-2. (Cont.)

NPTS

5

LX(N), LY(N)

1 24 2 24 2 25 3 25 3 45

NPTS

38

LX(N), LY(N)

3	25	12	25	13	26	14	27	15	28	16	29	17	30	18	31	19	32	20	33
21	34	22	33	23	32	24	31	25	30	26	29	27	28	28	27	29	26	30	25
29	24	28	23	27	22	26	21	25	20	24	19	23	18	22	17	21	16	20	17
19	18	18	19	17	20	16	21	15	22	14	23	13	24	12	25				

Appendix B PROGRAM LISTINGS

The Fortran program listings for FVSOLVR and FVPLOT which follow are current as of the date of publication of this report. These listings supersede those given in CEL Technical Note N-1502. Revisions are made periodically as deemed necessary; however these changes are usually concerned with minor details. Several versions of FVSOLVR and FVPLOT exist. For sake of brevity only one version of each is listed here.

The version of FVSOLVR given here is applicable to geometries which have axial symmetry. Other versions apply to two-dimensional cartesian coordinate systems which may or may not have planes of symmetry.

FVSOLVR uses three tapes (or disks) during execution. Tape 33 and tape 34 are used only as "scratchpads" during execution of the algorithm. Upon completion of the program execution tape 10 contains NX, NY, HX(NX), HY(NY), and V(NX,NY), the last array being the nodal solutions.

The version of FVPLOT given here yields Calcomp plots for 11-in.-wide paper. The plots are drawn such that the smallest dimension of a rectangular plot is scaled to a width of 10 inches. Field solution data from FVSOLVR are read from tape 10 (potential solution data) and tape 12 (flux solution data).

For completeness, the optional data-check program listings are provided. BDYCHK aids in verification of placement of dielectric boundaries. EPSCHK aids in verification of assignment of dielectric constants to the appropriate regions.

```

PROGRAM FVSOLVR
C
C FIELD VALUE SOLVER (AXIAL SYMMETRY)
C
      DIMENSION HX(100),HY(200),HV(99),HM(200),AN(99),
      1EPSR(199,10),EPS7(99,10),ANEPS(99),RHN(99),SYM(200,4),
      27EPS1(99),V(100,200),R(200),AR(100,200)
      DIMENSION GH(200),VG(200)
      INTEGER RDR(199,10),RDZ(99,10)
      INTEGER BLNK
      COMMON/RANARG/NDPN,NUMRLK,RFAM,NN,NN2,V,NX,NY,LX,LY,M,NCK8
      COMMON/HORARG/RDR,EPSR
      COMMON/VERARG/RDZ,EPSZ
      COMMON/SPARG/GH,VG,HM
      DATA BLNK/4H /
      DATA AR/20000*0.0/,SYM/800*0.0/,R/200*0.0/,V/20000*1.0/
C
C FORMAT STATEMENTS
C
      1 FORMAT(10F8.0)
      2 FORMAT(20I4)
      3 FORMAT(16F5.0)
      4 FORMAT(4F10.3)
      5 FORMAT(1H1,4HNY Z,T4,4X,4HNY Z,T4)
      6 FORMAT(1H ,A1,3HHX(,T3,3H) Z,FA.3,4(A4,6X,3HHX(,T3,3H) Z,FA.3))
      7 FORMAT(1H ,A1,3HHY(,T3,3H) Z,FA.3,4(A4,6X,3HHY(,T3,3H) Z,FA.3))
      8 FORMAT(1H1,9X,1H4,14FA.3)
      9 FORMAT(10X,1H4,14FA.3)
      10 FORMAT(10X,1H4,14(FH=====+====))
      11 FORMAT(1H0,15HTINITIAL VALUE Z,FA.3)
      12 FORMAT(1H0,6HNPTS Z,T5)
      13 FORMAT(1X,7HNUMRLKZ,T5)
      14 FORMAT(1X,5HNCK5Z,T5)
      15 FORMAT(1X,ANNTESTZ,T5)
      16 FORMAT(13H NONSYMMETRIC)
      17 FORMAT(1H1)
      18 FORMAT(1H )
      19 FORMAT(1H )
      20 FORMAT(1H0)
      21 FORMAT(1H=)
      22 FORMAT(1H ,27HREADY TO BEGIN CALCULATIONS)
      23 FORMAT(2T8,4F12.3)
      24 FORMAT(1H0,T4,36H ERRORS IN SEQUENCE OF HX OR HY DATA)
C
C INITIALIZATION
C
      READ 2,NX,NY,NFPR,NEPZ,IFSKIP,IERDY
      PRINT 5 ,NX,NY
      PRINT 20
      NXM1=NX-1
      NYM1=NY-1
      UNSNY
      NN2=NN*2
      NN1=NN+1
      REWIND 10
      REWIND 33
      REWIND 34
C
C READ GRID DATA
C
      READ 1 ,(HX(T),T=1,NX)

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```

K1=0
NCOL=NXM1/50
GOTO 120
100 NCOL=NCOL+1
120 TNK=NCOL*50
130 K1=K1+1
K2=K1+TNK
PRINT A,(PLNK,K,HY(K),K=K1,K2,50)
TF (K1,EQ,50,OR,K1,EQ,NY) GOTO 140
TF (K2,EQ,NY) 100,130
140 READ 1,(HY(I,J),J=1,NY)
PRINT 18
K1=0
NCOL=NYM1/50
GOTO 170
150 NCOL=NCOL+1
170 TNK=NCOL*50
180 K1=K1+1
K2=K1+TNK
PRINT 7,(PLNK,K,HY(K),K=K1,K2,50)
TF (K1,EQ,50,OR,K1,EQ,NY) GOTO 200
TF (K2,EQ,NY) 150,180
200 READ 2,((RD(I,J),J=1,NEPR),I=1,NYM1)
220 READ 2,KN,KN,KK
READ 3,(EPSR(KN,K),K=1,KK)
TF (KN,EQ,KN) GOTO 260
K1=KN+1
DO 240 I=K1,KN
DO 240 K=1,KK
240 EPSR(I,K)=EPSR(KN,K)
260 TF (KK,EQ,NEPR) GOTO 300
K=KK+1
DO 280 I=KN,KN
DO 280 J=KP,NEPR
280 EPSR(I,J)=EPSR(I,KK)
300 TF (KN,LT,NYM1) GOTO 220
READ 2,((RD2(I,J),J=1,NEPZ),I=1,NXM1)
320 READ 2,KN,KN,KK
READ 3,(EPSZ(KN,K),K=1,KK)
TF (KN,EQ,KN) GOTO 360
K1=KN+1
DO 340 I=K1,KN
DO 340 K=1,KK
340 EPSZ(I,K)=EPSZ(KN,K)
360 TF (KK,EQ,NEPZ) GOTO 400
K=KK+1
DO 380 I=KN,KN
DO 380 J=KP,NEPZ
380 EPSZ(I,J)=EPSZ(I,KK)
400 TF (KN,LT,NXM1) GOTO 320
TF (IFRDY,EQ,0) GOTO 550
C
C      INTERPOLATE FINE GRID BOUNDARY POTENTIALS
C      FROM COARSE GRID POTENTIAL SOLUTION
C
READ 2,NGX,NGY
READ 4,(GH(I),I=1,NGX)
READ 4,(VG(I),I=1,NGY)
CALL SPCNEF (NGX)
DO 450 I=1,NX

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```
450 V(T,NY)=SPLINE(NGX,HX(T))  
READ 4,(GH(T),T=1,NGY)  
READ 4,(VG(T),T=1,NGY)  
CALL SPCOFF (NGY)  
DO 500 T=1,NYM1  
500 V(NY,T)=SPLINE(NGY,HY(T))  
C  
C      READ BOUNDARY CONDITIONS  
C  
550 READ 2,NPOTS  
PRINT 1A  
DO 600 N=1,NPOTS  
READ 1,POT  
PRINT 12,POT  
READ 2,NLTNS  
PRINT 2,NLTNS  
DO 600 K=1,LTNS  
READ 2,L1,L2,M1,M2  
PRINT 2,L1,L2,M1,M2  
DO 600 J=L1,L2  
DO 600 J=M1,M2  
600 V(T,J)=POT  
C  
C      PARAMETER INITIALIZATION  
C  
NUMBLK=0  
NCK=0  
NCK1=1  
NCK4=NN  
NCK5=0  
NCKA=0  
NCNT=0  
NSYM=0  
LY=2  
Z=(HY(1)+HY(2))/2.  
ZPH=(HY(2)+HY(3))/2.  
NUMX=NY-1  
TF (HX(1),NE,0.01 NUMX=NY-2  
NPTSENUMX*(NY-2)  
PRINT 20  
PRINT 13,NPTS  
NCK7=NPTS-NUMX  
NDTAGE=1  
NDP1=ENDIAG+1  
NDPNE=ENDIAG+NUMX  
PRINT 1A  
DO 650 K=1,NYM1  
650 ZEPS1(K)=EPS7/(K,1)  
C  
C      CALCULATE DISTANCES BETWEEN GRID LINES  
C  
DO 700 J=1,NYM1  
HN(J)=HY(J+1)-HY(J)  
700 TF (HN(J),LE,0.) NCK6=NCK6+1  
DO 720 J=1,NYM1  
HM(J)=HY(J+1)-HY(J)  
720 TF (HM(J),LE,0.) NCK6=NCK6+1  
TF (NCK6,EQ,0) GOTO 740  
PRINT 24,NCKA
```

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C CALCULATE AREAS OF HORIZONTAL FACES, SET RHN ARRAY
C

740 R=HXR(1)
AN(1)=0.5*HN(1)*(R+HN(1))/4.
RHN(1)=R+HN(1)/2.
DO 750 J=2,NXM1
RHN(J)=(HXR(J)+HXR(J+1))/2.
750 AN(J)=(RHN(J)*2-RHN(J-1)*2)/2.

C BOTTOM EDGE AREA = EPS DATA SET-UP
C

FPS1=EPSR(1,1)
R=HXR(1)
LX=1
J=1
CALL HORIZ(1,J,EPS1,R,RHN(LX)+ANFPS(LX),AN(LX),LX,HXR(LX))
DO 800 LX=2,NXM1
J=1
CALL HORIZ(1,J,EPS1,RHN(LX-1),RHN(LX),ANFPS(LX),AN(LX),LX,HXR(LX))
800 CONTINUE
PRINT 22
IF (JFSKTP.NE.0) GOTO 5000
IF (NCK6.GT.0) GOTO 6000
PRINT 20
GOTO 3000

C SHIFT BLOCK UP AND ZERO
C

900 DO 1000 K=1,NN
KPNN=K+NN
DO 950 T=1,4
SYM(K,T)=SYM(KPNN,T)
950 SYM(KPNN,T)=0.0
R(KPNN)=0.0
DO 1000 I=1,NN
1000 AR(I,KPNN)=0.0

C CALCULATE BLOCK OF AR, R ARRAY VALUES
C

3000 DO 3600 L=NNP1,NN2
IF (NCK.EQ.0) GOTO 3010
LX=LX+1
R=HXR(LX)
IF (LX.LT.NX) GOTO 3400
LY=LY+1
IF (LY.EQ.NY) GOTO 4000
7=7PH
7PH=HY(LY)+HM(LY)/2.
3010 J=1
NCK=NCK+1
FPS1=EPSR(LY,1)
IF (HXR(1).NE.0.0) GOTO 3200
LX=1
R=0.0
IF (V(LX,LY).GE.0.0) GOTO 3500
SYM(L,1)=0.0
SYM(L,3)=ANFPS(1)/HM(LY-1)
CALL HORIZ(LY,J,EPS1,R,RHN(LY),ANFPS(LY),AN(LX1,LX,HXR(LX))
SYM(L,4)=ANFPS(1)/HM(LY)
CALL VERT(LX,7FPS1(LX),Z,ZPH,RHN(LY),A7EPS,LY,HY(LY))

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```
SYM(L,2)=A7EPS/HN(LX)
AR(NDIAG,L)=-SYM(L,1)-SYM(L+2)-SYM(L,3)-SYM(L,4)
TF (V(LX,LY-1),LT,0,0) GOTO 3170
R(L)=-V(LX,LY-1)*SYM(L,3)
SYM(L,3)=0.0
3170 TF (V(LX+1,LY),LT,0,0) GOTO 3180
R(L)=R(L)-V(LX+1,LY)*SYM(L,2)
SYM(L,2)=0.0
3180 TF (V(LX,LY+1),LT,0,0) GOTO 3190
R(L)=R(L)-V(LX,LY+1)*SYM(L,4)
SYM(L,4)=0.0
3190 AR(NDP1,L)=SYM(L,2)
AR(NDPN,L)=SYM(L,4)
GOTO 3600
3200 LX=2
R=HX(LX)
TF (V(LX,LY),GF,0,0) GOTO 3530
SYM(L,3)=ANEPS(2)/HM(LY-1)
CALL HORTZ(LY,J,FPS1,RHNN(LX),ANEPS(LX),AN(LX),LY,HX(LX))
SYM(L,4)=ANEPS(2)/HM(LY)
CALL VERT(LX+1,2FPS1(LX-1),Z,ZPH,RHNN(LX-1),A7EPS,LY,HY(LY))
SYM(L,1)=A7EPS/HN(LX-1)
CALL VERT(LX,2FPS1(LX),Z,ZPH,RHNN(LX),A7EPS,LY,HY(LY))
SYM(L,2)=A7EPS/HN(LX)
AR(NDIAG,L)=-SYM(L,1)-SYM(L,2)-SYM(L,3)-SYM(L,4)
R(L)=-V(LX,LY)*SYM(L,1)
SYM(L,1)=0.0
TF (V(LX,LY-1),LT,0,0) GOTO 3270
R(L)=R(L)-V(LX,LY-1)*SYM(L,3)
SYM(L,3)=0.0
3270 TF (V(LX+1,LY),LT,0,0) GOTO 3280
R(L)=R(L)-V(LX+1,LY)*SYM(L,2)
SYM(L,2)=0.0
3280 TF (V(LX,LY+1),LT,0,0) GOTO 3290
R(L)=R(L)-V(LX,LY+1)*SYM(L,4)
SYM(L,4)=0.0
3290 AR(NDP1,L)=SYM(L,2)
AR(NDPN,L)=SYM(L,4)
GOTO 3600
3300 AR(NDIAG,L)=1.
R(L)=V(LX,LY)
CALL HORTZ(LY,J,FPS1,R,RHNN(LX),ANEPS(LX),AN(LX),LY,HX(LX))
CALL VERT(LX,2FPS1(LX),Z,ZPH,RHNN(LX),A7EPS,LY,HY(LY))
GOTO 3600
3330 AR(NDIAG,L)=1.
R(L)=V(LX,LY)
CALL HORTZ(LY,J,FPS1,RHNN(LX-1),RHNN(LX),ANEPS(LX),AN(LX),LY,HX(LX))
CALL VERT(LX,2FPS1(LX),Z,ZPH,RHNN(LX),A7EPS,LY,HY(LY))
GOTO 3600
3400 TF (V(LX,LY),GF,0,0) GOTO 3530
SYM(L,3)=ANEPS(LX)/HM(LY-1)
CALL HORTZ(LY,J,FPS1,RHNN(LX-1),RHNN(LX),ANEPS(LX),AN(LX),LY,HX(LX))
SYM(L,4)=ANEPS(LX)/HM(LY)
SYM(L,1)=A7EPS/HN(LX-1)
CALL VERT(LX,2FPS1(LX),Z,ZPH,RHNN(LX),A7EPS,LY,HY(LY))
SYM(L,2)=A7EPS/HN(LX)
AR(NDIAG,L)=-SYM(L,1)-SYM(L,2)-SYM(L,3)-SYM(L,4)
TF (V(LX-1,LY),LT,0,0) GOTO 3460
R(L)=-V(LX-1,LY)*SYM(L,1)
SYM(L,1)=0.0
```

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```
3460 TF (V(LX,LY=1),LT,0,0) GOTO 3470
  R(L)=B(L)=V(LX,LY=1)*SYM(L,3)
  SYM(L,3)=0.0
3470 TF (V(LX+1,LY),LT,0,0) GOTO 3480
  R(L)=B(L)=V(LX+1,LY)*SYM(L,2)
  SYM(L,2)=0.0
3480 TF (V(LX,LY+1),LT,0,0) GOTO 3490
  R(L)=B(L)=V(LX,LY+1)*SYM(L,4)
  SYM(L,4)=0.0
3490 AR(NDP1,L)=SYM(L,2)
  AR(NDP1,L)=SYM(L,4)
3500 CONTINUE
4000 NTEST=3
C
C      WRITE BLOCK OF AR, B ARRAY VALUES ONTO TAPE
C
      WRITE(34)(R(N),AR(NDTAG,N),AR(NDP1,N),AR(NDP1,N),NENNP1,NN2)
      NTEST=4
      NUMBLK=NUMBLK+1
      NCNT=NUMBLK*NN
      TF(NUMLBLK,EQ,1)GOTO 4300
C
C      CHECK MATRIX SYMMETRY
C
4100 DO 4200 L=NCK1,NCK4
      NCK5=NCK5+1
      NCK2=L+1
      NCK3=L+NUMY
      TF (SYM(L,2),NE,SYM(NCK2,1)) GOTO 4150
      TF(NCK5,GT,NCK7)GOTO 4200
      TF (SYM(L,4),EQ,SYM(NCK3,3)) GOTO 4200
4150 PRINT 17
      NSYM=NSYM+1
      PRINT 23,NUMLBLK,NCK5,SYM(NCK2,1),SYM(1,2),SYM(NCK3,3),SYM(L,4)
4200 CONTINUE
      TF(NCK1,EQ,NNP1)GOTO 4500
4300 TF(NCNT,LT,NPTS)GOTO 900
      NCK1=NNP1
      NCK4=NNP1+NPTS-NCK5+1
      GOTO 4100
4500 CONTINUE
      PRINT 15,NCK5
      NCK8=NPTS-(NUMLBLK-1)*NN
      PRINT 2,NCK8
      TF (NSYM,GT,0) GOTO 5000
C
C      ZERO AR AND B ARRAYS
C
      DO 4800 J=1,NNP
      R(J)=0.0
      DO 4800 I=1,NN
4800 AR(L,J)=0.0
C
C      CALL BANDED MATRIX SOLVER
C
      M=1
      TF (HX(1),NE,0,0) M=2
      CALL BANSOL(AR,NDP1,NN2)
      NTEST=5
      PRINT 2,LX,LY
```

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```
C          WRITE SOLUTION ONTO TAPE
C
C          WRTTE(10) NX,NY
C          CALL WRT10(HX,NX)
C          CALL WRT10(HY,NY)
C          DO 4900 J=1,NY
4900 CALL WRT10(V(1,J),NX)
        END FILE10
C          PRINT SOLUTION
C
5000 M2=0
M1=50
5100 M2=M2+50
IF (M2.LT.NY) GOTO 5200
M1=NY+50-M2
M2=NY
5200 N2=0
5300 N1=N2+1
N2=N2+14
IF (N2.GT.NX) N2=NY
NPRT=N2-N1+1
PRINT  A ,(HX(K),K=N1,N2)
PRINT  10
DO 5400 J=1,M1
T=M2+1-J
5400 CALL PRTY(HY(T)),V(N1,J),NPRT)
PRINT  10
PRINT  9 ,(HY(K),K=N1,N2)
IF (N2.LT.NX) GOTO 5300
IF (M2.LT.NY) GOTO 5100
6000 CONTINUE
STOP
END
C          SUBROUTINE RANSOL(A,N1,N2)
C          SOLVES BANDED, SYMMETRIC MATRIX
C
DIMENSION B(200),AR(100,200),V(100,200)
DIMENSION A(N1,N2)
COMMON /RANARG/ MM,NUMBLK,B,AR,NN,NN2,V,NX,NY,LX,LY,LHR,NCK8
NL=NN+1
NH=NN+NN
LY=NY
LY-NY=1
REWIND 34
NB=0
GO TO 150
C          REDUCE EQUATIONS BY BLOCKS
C
C          1. SHIFT BLOCK OF EQUATIONS
C
100 NR=NR+1
DO 125 NM=1,NN
NM=NN+NM
B(N)=B(NM)
B(NM)=0.0
125
```

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```
DO 125 M=1,MM
  A(M,N)=A(M,NM)
125  A(M,NM)=0.0
C
C      2. READ NEXT BLOCK OF EQUATIONS INTO CORE
C
C      IF (NUMBLK=NRI) 150,200,150
150  READ (34) (A(I,N),A(1,N),A(2,N),A(MM,N),NENL,NH)
      TF (NRI) 200,100,200
C
C      3. REDUCE BLOCK OF EQUATIONS
C
C      200 DO 300 N=1,NN
      TF (A(1,N)) 225,300,225
225  R(N)=B(N)/A(1,N)
      DO 275 L=2,MM
      TF (A(L,N)) 230,275,230
230  R=L/A(1,N)/A(1,N)
      T=N+L-1
      J=0
      DO 250 K=L,MM
      J=J+1
250  A(J,T)=A(J,T)-C*A(K,N)
      R(T)=B(I)=A(L,N)*B(N)
      A(L,N)=0
275  CONTINUE
300  CONTINUE
C
C      4. WRITE BLOCK OF REDUCED EQUATIONS ON TAPE 2
C
C      TF (NUMBLK=NRI) 375,400,375
375  CALL ROWRT33(B,A(1,1),NN,MM+1)
      GO TO 100
C
C      BACK-SUBSTITUTION
C
C      400 DO 450 K=1,NN
      N=NN+1-M
      DO 425 K=2,MM
      L=N+K-1
425  R(N)=B(N)-A(K,N)*B(L)
      NM=N+NN
      R(NM)=B(N)
      TF (NR,EQ,NUMBLK,AND,N,GT,NCK8) GOTO 450
      LX=LX+1
      IF (LX,GE,LHR) GOTO 445
      LY=LY+1
      LX=LX+1
      445  V(LX,LY)=B(N)
450  CONTINUE
      NR=NR+1
      TF (NR) 475,500,475
475  CONTINUE
      CALL ROWRT33(B,A(1,1),NN,MM+2)
      GO TO 400
500  CONTINUE
C
C      RETURN
C
END
```

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```
C          SUBROUTINE RDWR33(B,A,N,M,INDX)
C          DIMENSION B(N),A(M,N)
C          DIMENSION MDX(400)
C          DATA NW/0/
C          TF(NW,NF,0) GO TO 5
C          CALL OPENMS(33,MIDX,400,0)
C          KRN
C          KA$NM
C          TF(INDX,NF,1) GO TO 10
C          WRITE
C          NW$NW+1
C          CALL WRITMS(33,B,KR,NW)
C          NW$NW+1
C          CALL WRITMS(33,A,KA,NW)
C          GO TO 20
C          READ
C          10  CALL READMS(33,A,KA,NW)
C          NW$NW+1
C          CALL READMS(33,B,KR,NW)
C          NW$NW+1
C          DONE
C          20  CONTINUE
C          RETURN
C          END
C          SUBROUTINE WRT10(A,N)
C          DIMENSION A(N)
C          WRITE(10) A
C          RETURN
C          END
C          SUBROUTINE PRTY(A,R,N)
C          DIMENSION R(N)
C          PRINT 11,A,R
C          11  FORMAT(1X,FA.3,2H +,14FA.3)
C          RETURN
C          END
C          SUBROUTINE HORTZ(LY,J,EP$1,RA,RB,ANEP$,AREA,LX,R)
C          CALCULATES ELECTRIC-AREA PRODUCT
C          OF HORIZONTAL FACE OF VOLUME ELEMENT
C          DIMENSION EP$(199,10)
C          INTEGER RDR(199,10)
C          COMMON/HORTARG/RDR,EP$,
C          TF (RDR(LY,J)=2*LX) 1,2,3
C          1 J=J+1
C          EP$1=EP$(LY,J)
C          TF (RDR(LY,J)=2*LX) 1,2,3
C          2 J=J+1
C          EP$2=EP$(LY,J)
C          ANEP$=0.5*((EP$1+EP$2)*R**2+EP$2*RA**2-EP$1*RA**2)
C          EP$1=EP$2
C          RETURN
C          3 ANEP$=EP$1*RA
C          RETURN
C          END
C          SUBROUTINE VERT(LX,EP$1,Z,ZPH,R,AZEP$,LY,Y)
```

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```
C      CALCULATES DIELECTRIC-AREA PRODUCT
C      OF VERTICAL FACE OF VOLUME ELEMENT
C
C      DIMENSION EPS(99,10)
C      INTEGER RDZ(99,10)
C      COMMON/VERARG/RDZ,EPS
C      K#1
C      IF (RDZ(LX,K)=2*LY) 1,2,3
1     K#K+1
      EPS1=EPS(LX,K)
      IF (RDZ(LX,K)=2*LY) 1,2,3
2     K#K+1
      EPS2=EPS(LX,K)
      AZEPS=R*(EPS1*(Y-Z)+EPS2*(ZPH-Y))
      EPS1=EPS2
      RETURN
3     AZEPS=EPS1*R*(ZPH-7)
      RETURN
      END
C
C      SUBROUTINE SPACEF (N)
C      CALCULATES COEFFICIENTS OF CUBIC SPLINE USED IN INTERPOLATION
C
C      DIMENSION XN(200),FN(200),S(200),RHO(200),TAU(200)
C      COMMON/SPARG/XN,FN,S
C      NM1#N=1
C      NM2#N=2
C      RHO(2)=0.0
C      TAU(2)=0.0
C      DO 1 T=2,NM1
C      TM1#T=1
C      TP1#T+1
C      HTM1=XN(T)-XN(TM1)
C      H1=XN(TP1)-XN(T)
C      TEMP=(HTM1/HT1)*(RHO(T)+2.0)+2.
C      RHO(T+1)=1./TEMP
C      D=6.*((FN(TP1)-FN(T))/HT1-(FN(1)-FN(TM1))/HTM1)/HT
1     TAU(T+1)=(D-HTM1*TAU(T))/H11/TEMP
      S(1)=0.
      S(N)=0.
      DO 2 I=1,NM2
      TRH=N-T
2     S(TH)=RHO(TRH)*S(TH+1)+TAU(TH+1)
      RETURN
      END
C
C      FUNCTION SPLINE (N,X)
C      EVALUATES SPLINE FUNCTION
C
C      DIMENSION XN(200),FN(200),S(200)
C      COMMON/SPARG/XN,FN,S
C      TF (X,GE,XN(1)) GOTO 1
C      H1#XN(2)=XN(1)
C      SPLINE=FN(1)+(X-XN(1))*((FN(2)-FN(1))/H1+H1*S(2)/6.)
C      RETURN
1     TF (X,LE,XN(N)) GOTO 2
      NM1#N=1
      HNN=(XN(N)-XN(NM1))
      SPLINE=(FN(N)+FX-XN(N))*((FN(N)-FN(NM1))/HNN+HNN*S(NM1)/6.)
      RETURN
```

```
2 DO 3 I=2,N
  TF (X,I,E,XN(T)) GOTO 4
3 CONTINUE
4 L=I-1
  LP1=I+1
  A=YN(LP1)-Y
  R=Y-XN(L)
  HL=XN(LP1)-XN(L)
  SPLINE=A*S(L)*(A**2/HL+HL)/E+R*S(L+1)*(R**2/HL+HL)/6.
  / +(A*FN(L)+R*FN(LP1))/HL
  RETURN
END
```

```

C PROGRAM FVPLOT
C
C CONTOUR LINE PLOTTER
C
C
C DIMENSION V(100,200),HX(100),HY(200),IPUF(60),GX(100),GY(200),
C /U(100,200),LX(150),LY(150)
C COMMON/DRAWARG/X(600),Y(600),XMAX,YMAX,NQUAD,FRSTX,DELTAX,FRSTY,
C /DELTAY
C 1 FORMAT(8F10.3)
C 2 FORMAT(20I4)
C 3 FORMAT(6I4,2F5.0)
C 4 FORMAT(I4)
C 5 FORMAT(5H1NX Z,T4,6X,4HNY Z,I4)
C 6 FORMAT(1H0,T13,I14,T24,T14)
C 7 FORMAT(7H0X F0M,F10.3,4H TU,F10.3,8X,6H Y F0M,F10.3,4H TO,
C 1F10.3)
C
C READ POTENTIAL GRID DATA
C
C
C READ 4 ,IVU
C READ 3 ,IN,TN,JN,JN,NQUAD,KK,VMTN,S2
C IPNT=S2
C READ (10) NX,NY
C CALL RD10(HX,NX)
C CALL RD10(HY,NY)
C DO 80 J=1,NY
C 80 CALL RD10(V(1,J),NX)
C TSCAN=1
C IF (IVU.EQ.1) GOTO 150
C
C READ FLUX GRID DATA
C
C
C READ (12) MX,MY
C CALL RD10(GX,MX)
C CALL RD10(GY,MY)
C DO 90 J=1,MY
C 90 CALL RD10(U(1,J),MX)
C NHZ1
C NHZ2
C KPA=1
C
C SHIFT DATA FOR REGION TO BE PLOTTED
C
C
C IF (TN.EQ.1) GOTO 120
C DO 100 I=IN,TN
C GX(I+1-JN)=GX(I)
C DO 100 J=1,MY
C 100 U(I+1-TN,J)=U(I,J)
C 120 MX=IN+1-TN
C IF (JN.EQ.1) GOTO 150
C DO 130 J=JN,JN
C GY(J+1-JN)=GY(J)
C DO 130 I=1,MY
C 130 U(I,J+1-JN)=U(I,J)
C 150 TF (TN.EQ.1) GOTO 170
C DO 160 I=IN,TF
C HX(I+1-TN)=HY(I)
C DO 160 J=1,MY
C 160 V(I+1-TN,J)=V(I,J)
C 170 NX=IN+1-TN

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```
      IF (JN,EQ,1) GOTO 200
      DO 180 J=JN,JN
      HY(J+1-JN)=HY(J)
      DO 180 I=1,NX
      180 V(T,J+1-JN)=V(T,J)
      200 NY=JN+1-JN
      PRINT 5 ,NX,NY
      PRINT 6 ,T0,TN,JN,JN
      PRINT 7 ,HX(1),HY(NX),HY(1),HY(NY)
      YMAX=HX(NX)=HX(1)
      YMAX=HY(NY)=HY(1)
      NX1=NY=1
      NY1=NY=1

C
C      INITIALIZE PLOT AND DRAW AXES
C
      CALL PLOTS (11,0,99)
      CALL PLOT (0.,-14.,-3)
      CALL PLOT(0.,0.5,-3)
      FIRSTX=HX(1)
      FIRSTY=HY(1)
      IF (XMAX,GT,YMAX) GOTO 220
      IF (INQUAD,EQ,2,AND,(2.+XMAX),LT,YMAX) GOTO 220
      DELTAX=XMAX/10.
      DELTAY=DELTAX
      GOTO 240
      220 DELTAY=YMAX/10.
      DELTAX=DELTAY
      IF (INQUAD,EQ,2) GOTO 280
      240 IF (INQUAD,GT,1) GOTO 280
      IF (XMAX,GT,YMAX1) GOTO 260
      VAYS=(YMAX/YMAX1)*10.
      CALL AXIS(0.,10.,27HZ=AXTS      AXIS OF SYMMETRY,+27,YAX,0.,FIRSTY,
      1DELTAY,0)
      CALL AXIS(0.,10.,AHR=AXTS,-6,10.,270.,FIRSTX,DELTAX,0)
      GOTO 280
      260 XAY=(XMAX/YMAX)*10.
      CALL AXIS(0.,0.,27HZ=AXTS      AXIS OF SYMMETRY,+27,10.,90.,FIRSTY,
      1DELTAY,0)
      CALL AXIS(0.,0.,AHR=AXTS,-6,XAX,0.,FIRSTX,DELTAX,0)
      GOTO 280
      280 DELTAX=2.*DELTAX
      DELTAY=2.*DELTAY
      290 IF (TVU,EQ,2) GOTO 305
C
C      DRAW EQUIPOTENTIAL LINES
C
      DO 300 K=1,KK
      300 CALL DRAW (Z,NX,NY,NX1,NY1,HX,HY,V,ISCAN)
      IF (TVU,EQ,3) 305,500
C
C      CALCULATE AND PLOT FLUX LINE DISTRIBUTION
C
      305 NX1=HY=1
      NY1=HY=1
      T=1
      PA=V(1,1)
      310 T=T+1
      PB=V(1,I)
      320
```

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```
TF (UPOT,GF,PA,AND,UPOT,LE,PR) GOTO 320
RA=PR
GOTO 310
320 IM=I=1
R=HY(IM)+(UPOT-PA)*(HY(I)-HY(IM))/(PR-PA)
H=HY(NH)=HY(MH)
TSCAN=2
C=0.
RA=HY(KRA)
330 KRA=KRA+1
TF (KRA,GT,MX) GOTO 500
R=HY(KRA)
FA=(V(KRA,NH)-V(KRA,MH))/H
FB=(V(KRA,NH1)-V(KRA,MH))/H
A2=((FA-FB)/(RR-RA))/2.
A1=EA=RA*2.*AP
CINC=A2*(RR**2-RA**2)+A1*(RH-RA)
TF (R,LT,RR) CINC=A2*(R**2-RA**2)+A1*(R-RA)
C=C+CINC
TF (R,LE,RR) GOTO 340
KRA=KRA
RA=RR
GOTO 330
340 Z=U(KRA,MH)+(R-RA)*(U(KRA,MH)-U(KRA,MH))/ (RH-RA)
CALL DRAW (Z,NX,NY,NX1,NY1,GX,GY,U,TSCAN)
RX=R
CSUM=0.
350 A2=((FA-FB)/(RR-RA))/2.
A1=EA=RA*2.*AP
CINC=AP*(RR**2-RX**2)+A1*(RH-FX)
TF (C-CSUM-CINC) 380,390,370
370 CSUM=CSUM+CINC
KRA=KRA
KRA=KRA+1
TF (KRA,GT,MY) GOTO 500
RA=RR
RX=RA
R=HY(KRA)
FA=(V(KRA,NH)-V(KRA,MH))/H
FB=(V(KRA,NH1)-V(KRA,MH))/H
GOTO 360
380 A0=CSUM-(C+AP*RX**2+A1*RX)
CALL RSLVER(R,RX,RR,A2,A1,A0)
GOTO 400
390 R=RR
400 Z=U(KRA,MH)+(R-RA)*(U(KRA,MH)-U(KRA,MH))/ (RR-RA)
CALL DRAW (Z,NX,NY,NX1,NY1,GX,GY,U,TSCAN)
TF (TSCAN,FE,0) GOTO 500
TF (R,NE,RR) GOTO 350
KRA=KRA
KRA=KRA+1
TF (KRA,GT,MY) GOTO 500
R=HY(KRA)
RA=RR
GOTO 350
C
C      DRAW ELECTRODE AND DIELECTRIC CONFIGURATION
C
500 READ 3 ,NLINES
DO 700 L=1,NLINES
```

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```
READ 3,NPTS
READ 2,((X(N),LY(N),N=1,NPTS)
IF (XMAX.GT.YMAX) GOTO 600
IF (NQUAD.EQ.2.AND.(2.*XMAX).GT.YMAX) GOTO 600
DO 540 N=1,NPTS
LXNNN=LX(N)+1-J0
LYNNN=LY(N)+1-J0
Y(N)=HY(LYNNN)
GOTO (510,530,520,520),NQUAD
510 X(N)=XMAX-HX(LYNNN)
GOTO 540
520 Y(N)=YMAX-HY(LYNNN)
530 X(N)=XMAX+HX(LYNNN)
540 CONTINUE
X(NPTS+1)=FIRSTX
X(NPTS+2)=DELTAX
Y(NPTS+1)=FIRSTY
Y(NPTS+2)=DELTAY
CALL LINE (Y,X,NPTS,1,0,0)
GOTO (700,580,550,550),NQUAD
550 DO 560 N=1,NPTS
560 X(N)=2.*YMAX-X(N)
CALL LINE (Y,X,NPTS,1,0,0)
DO 570 N=1,NPTS
570 Y(N)=2.*YMAX-Y(N)
CALL LINE (Y,X,NPTS,1,0,0)
580 DO 590 N=1,NPTS
590 X(N)=2.*YMAX-Y(N)
CALL LINE (Y,X,NPTS,1,0,0)
GOTO 700
600 DO 640 N=1,NPTS
LXNNN=LX(N)+1-J0
LYNNN=LY(N)+1-J0
Y(N)=HY(LYNNN)
GOTO (610,630,620,620),NQUAD
610 X(N)=HX(LXNNN)
GOTO 640
620 Y(N)=YMAX-HY(LYNNN)
630 X(N)=XMAX+HX(LYNNN)
640 CONTINUE
X(NPTS+1)=FIRSTX
X(NPTS+2)=DELTAX
Y(NPTS+1)=FIRSTY
Y(NPTS+2)=DELTAY
CALL LINE (X,Y,NPTS,1,0,0)
GOTO (700,680,650,650),NQUAD
650 DO 660 N=1,NPTS
660 X(N)=2.*XMAX-X(N)
CALL LINE (X,Y,NPTS,1,0,0)
DO 670 N=1,NPTS
670 Y(N)=2.*YMAX-Y(N)
CALL LINE (X,Y,NPTS,1,0,0)
680 DO 690 N=1,NPTS
690 X(N)=2.*XMAX-X(N)
CALL LINE (X,Y,NPTS,1,0,0)
700 CONTINUE
CALL PLOT(12.0,0.0,40)
STOP
END
```

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```
SUBROUTINE RD10(A,N)
DIMENSION A(N)
READ (10) A
RETURN
END

C
C SUBROUTINE DRAW (Z,IL,IL,II,JU,XV,YV,V,ISCAN)
C SCANS GRID AND PILOTS LINES OF EQUAL VALUE
C
C DIMENSION XV(100),YV(200),V(100,200)
C COMMON/DRAY/ARC/X(600),Y(600),XMAX,YMAX,NQUAD,FIRSTX,DELTAZ,FIRSTY,
/DELTAY
NT=0
TX=0
T=Z
TA=JL
DO 3 J=1,JJ
TA=J
A=V(TA,JA)
B=V(TA,JA+1)
TF (A,EQ,B) GO TO 3
TF (A,LE.0.,GE.B,LE.0.) GOTO 3
TF (A,EQ,T) 1,2
1 T=TA+(D-A)*1.E-6
2 CALL DA(D,A,T,XV,YV,X,Y,TA,JA,TX,NT,JJ,V)
TF (NT,NE.0) GO TO 30
3 CONTINUE
TA=JL
DO 6 I=1,II
TA=IL-I
A=V(TA+1,JA)
B=V(TA,JA)
TF (B,EQ,A) GO TO 6
TF (A,LE.0.,GE.B,LE.0.) GOTO 6
TF (B,EQ,T) 4,5
4 T=B+(A-B)*1.E-6
5 CALL AR(A,B,T,XV,YV,X,Y,TA,JA,TX,NT,II,V)
TF (NT,NE.0) GO TO 30
6 CONTINUE
TA=0
DO 10 J=1,JJ
TA=JL-J
C=V(1,JA+1)
B=V(1,JA)
TF (C,EQ,B) GO TO 10
TF (JA,EQ,1) GOTO 7
TF (C,LE.0.,GE.B,LE.0.) GOTO 10
7 TF (C,LE.0.,GE.B,LT.0.) GOTO 10
TF (C,EQ,T) 8,9
8 T=C+(B-C)*1.E-6
9 CALL BC(C,C,T,XV,YV,X,Y,TA,JA,TX,NT,II,V)
TF (NT,NE.0) GO TO 30
10 CONTINUE
TA=0
DO 14 I=1,II
TA=I
D=V(TA,1)
C=V(TA+1,1)
TF (D,EQ,C) GO TO 14
TF (TA,EQ,1,AND,ISCAN,EQ,2) GOTO 11
59
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```
10 TF (C,LE,0.,DR,D,LE,0.) GOTO 14
11 TF (C,LE,0.,DR,D,LT,0.) GOTO 14
12 TF (D,EQ,T) 12,13
13 T=D+(C-D)*1,F=6
14 CALL CD(C,D,T,XV,YV,X,Y,TA,JA,IX,NT,II,V)
   TF (NT,NE,0) GO TO 30
14 CONTINUE
   IF (TSCAN,NE,1) GOTO 22
   DO 21 I=1,II
   DO 21 J=1,JJ
   TA=I
   JA=J
   C=V(I+1,J+1)
   R=V(I+1,J)
   TF (C,FE,B) GO TO 18
   TF (J,FE,1) GOTO 15
   TF (C,LE,0.,DR,B,LE,0.) GOTO 18
15 TF (C,LE,0.,DR,B,LT,0.) GOTO 18
   TF (C,EQ,T) 16,17
16 T=C+(B-C)*1,F=6
17 CALL BC(B,C,T,XV,YV,X,Y,TA,JA,IX,NT,JJ,V)
   TF (NT,NE,0) GO TO 30
18 D=V(T,J+1)
   TF (C,EQ,D) GO TO 21
   TF (C,LE,0.,DR,D,LE,0.) GOTO 21
   TF (C,EQ,T) 19,20
19 T=C+(D-C)*1,F=6
20 CALL CD(C,D,T,XV,YV,X,Y,TA,JA,IX,NT,II,V)
   TF (NT,NE,0) GO TO 30
21 CONTINUE
   TSCAN=0
   GO TO 69
22 DO 29 J=1,JJ
   DO 29 I=1,II
   TA=I
   JA=J
   C=V(I+1,J+1)
   R=V(I+1,J)
   TF (C,FE,B) GO TO 25
   TF (C,LE,0.,DR,B,LE,0.) GOTO 25
   TF (C,EQ,T) 23,24
23 T=C+(B-C)*1,F=6
24 CALL BC(B,C,T,XV,YV,X,Y,TA,JA,IX,NT,JJ,V)
   TF (NT,NE,0) GO TO 30
25 D=V(T,J+1)
   TF (C,EQ,D) GO TO 29
   TF (T,FE,1) GOTO 26
   TF (C,LE,0.,DR,D,LE,0.) GOTO 29
26 TF (C,LE,0.,DR,D,LT,0.) GOTO 29
   TF (C,EQ,T) 27,28
27 T=C+(D-C)*1,F=6
28 CALL CD(C,D,T,XV,YV,X,Y,TA,JA,IX,NT,II,V)
   TF (NT,NE,0) GO TO 30
29 CONTINUE
   TSCAN=0
   GO TO 69
30 TST=IA
   TST=JA
31 TF (JA,FE,0,DR,TA,FE,IL,DR,JA,ER,0,DR,JA,EQ,JL) GO TO 50
   NIX=IX
```

```

TF (T, EQ, V(TA, JA)) V(TA, JA)=V(TA, JA)*1.0001
TF (T, EQ, V(TA+1, JA)) V(TA+1, JA)=V(TA+1, JA)*1.0001
TF (T, EQ, V(TA+1, JA+1)) V(TA+1, JA+1)=V(TA+1, JA+1)*1.0001
TF (T, EQ, V(TA, JA+1)) V(TA, JA+1)=V(TA, JA+1)*1.0001
ASV(TA, JA)
REV(TA+1, JA)
C8V(TA+1, JA+1)
D8V(TA, JA+1)
TF (TA, EQ, 1, AND, TSCAN, EQ, 21) GOTO 32
TF (JA, EQ, 1) GOTO 33
TF (A, LE, 0, , OR, B, LE, 0, , OR, C, LE, 0, , OR, D, LE, 0, ) GOTO 40
32 TF (A, LT, 0, , OR, B, LE, 0, , OR, C, LT, 0, , OR, D, LT, 0, ) GOTO 50
GOTO 34
33 TF (A, LT, 0, , OR, B, LT, 0, , OR, C, LE, 0, , OR, D, LE, 0, ) GOTO 50
34 TF (NT, EQ, 1) GO TO 35
TF (NT, EQ, 2) GO TO 36
TF (NT, EQ, 3) GO TO 37
TF (NT, EQ, 4) GO TO 38
GO TO 69
35 CALL DA(D, A, T, XV, YV, X, Y, TA, JA, TX, NT, JJ, V)
TF (TX, GT, NTIX) GOTO 39
CALL BC(B, C, T, XV, YV, X, Y, TA, JA, TX, NT, JJ, V)
TF (TX, GT, NTIX) GOTO 39
CALL AREA(B, T, XV, YV, X, Y, TA, JA, TX, NT, II, V)
GO TO 39
36 CALL AREA(B, T, XV, YV, X, Y, TA, JA, TX, NT, II, V)
TF (TX, GT, NTIX) GOTO 39
CALL CD(C, D, T, XV, YV, X, Y, TA, JA, TX, NT, II, V)
TF (TX, GT, NTIX) GOTO 39
CALL BC(B, C, T, XV, YV, X, Y, TA, JA, TX, NT, JJ, V)
GO TO 39
37 CALL BC(B, C, T, XV, YV, X, Y, TA, JA, TX, NT, JJ, V)
TF (TX, GT, NTIX) GOTO 39
CALL DA(D, A, T, XV, YV, X, Y, TA, JA, TX, NT, JJ, V)
TF (TX, GT, NTIX) GOTO 39
CALL CD(C, D, T, XV, YV, X, Y, TA, JA, TX, NT, II, V)
GO TO 39
38 CALL CD(C, D, T, XV, YV, X, Y, TA, JA, TX, NT, II, V)
TF (TX, GT, NTIX) GOTO 39
CALL AREA(B, T, XV, YV, X, Y, TA, JA, TX, NT, II, V)
TF (TX, GT, NTIX) GOTO 39
CALL DA(D, A, T, XV, YV, X, Y, TA, JA, TX, NT, JJ, V)
39 TF (TA, EQ, TST, AND, JA, EQ, JST) 50, 31
40 TF (X(TX), EQ, Y(TY-1)) GOTO 50
 $q = (Y(TY) - Y(TY-1)) / (X(TY) - X(TY-1))$ 
 $SR = Y(TY) - S * X(TY)$ 
41 SL = (YV(JA+1) - YV(JA)) / (XV(TA) - XV(TA+1))
SR = (YV(JA+1) - YV(JA)) / (XV(TA+1) - XV(TA))
ORTHL = ABS(SL + 1. / S)
ORTHR = ABS(SR + 1. / S)
TF (ORTHR, LT, ORTHL) GOTO 42
SR = YV(JA) - SL * XV(TA+1)
XR = (SR - SR) / (S - SL)
GOTO 43
42 SR = YV(JA) - SR * XV(TA)
XR = (SR - SR) / (S - SR)
43 TX = IX + 1
X(IX) = XR
Y(TX) = S * X(IX) + SR
50 CALL XPLNTY(X, Y, Z, TX)

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```
TF (YMAX,GT,YMAX) GOTO 60
IF (NQUAD,FQ,2,AND,(2,*XMAX),GT,YMAX) GOTO 60
DO 54 I=1,TX
  GOTO (51,53,52,52),NQUAD
51 Y(I)=XMAX-X(I)
  GOTO 54
52 Y(I)=YMAX-Y(I)
53 Y(I)=XMAX+X(I)
54 CONTINUE
  X(TX+1)=FIRSTX
  X(TX+2)=DELTAX
  Y(TX+1)=FIRSTY
  Y(TX+2)=DELTAY
  CALL LINE(Y,X,TX,1,0,0)
  GOTO (69,58,55,55),NQUAD
55 DO 56 I=1,TX
56 X(I)=2.*XMAX-X(I)
  CALL LINE(Y,X,TX,1,0,0)
  DO 57 I=1,TX
57 Y(I)=2.*YMAX-Y(I)
  CALL LINE(Y,X,TX,1,0,0)
  58 DO 59 I=1,TX
59 X(I)=2.*XMAX-X(I)
  CALL LINE(Y,X,TX,1,0,0)
  GOTO 60
60 GOTO (63,61,61,61),NQUAD
61 DO 62 I=1,TX
  X(I)=XMAX+X(I)
62 TF (NQUAD,FQ,4) Y(I)=2.*YMAX-Y(I)
63 X(TX+1)=FIRSTY
  X(TX+2)=DELTAY
  Y(TX+1)=FIRSTX
  Y(TX+2)=DELTAX
  CALL LINE(Y,X,TX,1,0,0)
  GOTO (69,67,64,64),NQUAD
64 DO 65 I=1,TX
65 X(I)=2.*XMAX-X(I)
  CALL LINE(Y,X,TX,1,0,0)
  DO 66 I=1,TX
66 Y(I)=2.*YMAX-Y(I)
  CALL LINE(Y,X,TX,1,0,0)
  67 DO 68 I=1,TX
68 Y(I)=2.*XMAX-X(I)
  CALL LINE(Y,X,TX,1,0,0)
  69 CONTINUE
  RETURN
END
```

```
C
C      SUBROUTINE RSOLV (R,RA,RB,A2,A1,A0)
C      CALCULATES ROOTS OF QUADRATIC EQUATION
C
  TF (A2,EQ,0.) GOTO 3
  RS=(-A1 + SQRT(A1**2 - 4.*A2*A0)) / (2.*A2)
  PRINT 1 ,R,RA,RB,A2,A1,A0
  1 FORMAT (4H R =,6E16.8)
  IF (R,GE,RA,AND,R,LE,RB) GOTO 2
  RS=(-A1 + SQRT(A1**2 - 4.*A2*A0)) / (2.*A2)
  PRINT 1 ,R,RA,RB,A2,A1,A0
  2 CONTINUE
  RETURN
```

```
3 R=A0/A1
PRINT 1 ,R,RA,RR,AP,A1,A0
RETURN
END

C
SUBROUTINE XPLOTY(X,Y,Z,TX)
PRINTS COORDINATES OF EQUAL VALUE LINES
C
DIMENSION X(1),Y(1)
PRINT 3
PRINT 4, Z
PRINT 2, TX
PRINT 5
PRINT 1, (X(K),Y(K),K=1,TX)
1 FORMAT(1H ,2F15.7,3(2X,2F15.7))
2 FORMAT(1H ,16,7H POINTS)
3 FORMAT(1H )
4 FORMAT(9H VALUE = ,F8.3)
5 FORMAT(1H ,1AHCOORDINATE PAIRS)
RETURN
END

C
SUBROUTINE ARYA,R,T,XV,YV,X,Y,IA,JA,TX,NT,JI,V)
SEARCHES BOTTOM SIDE OF RECTANGLE FOR GIVEN VALUE
C
DIMENSION XV(1),YV(1),X(1),Y(1),V(100,200)
TF (A,GT,T,AND,B,LT,T,OR,A,LT,T,AND,B,GT,T) 1,7
1 R1=XV(IA)
Q1=XV(IA+1)
XX=(P1+Q1)/2.
T1=IA
T2=JI
TF (IA,EQ,1) 2,3
2 R1=XV(TA+2)
T3=V(TA+2,JA)
CALL SOL33(XX,T,P1,Q1,R1,T1,T2,T3)
GO TO 6
3 TF (IA,EQ,JI) 4,5
4 R1=XV(IA-1)
T3=V(IA-1,JA)
CALL SOL33(XX,T,P1,Q1,R1,T1,T2,T3)
GO TO 6
5 TF (V(TA-1,JA),LF,0.) GOTO 2
TF (V(TA+2,JA),LF,0.) GOTO 4
R1=XV(TA-1)
S1=XV(TA+2)
T3=V(TA-1,JA)
T4=V(TA+2,JA)
CALL SOL44(XX,T,P1,Q1,R1,S1,T1,T2,T3,T4)
6 NT=1
IX=IX+1
X(IX)=XX
Y(IX)=YV(JA)
JA=JA+1
7 RETURN
END

C
SUBROUTINE RC(R,C,T,XV,YV,X,Y,IA,JA,TX,NT,JJ,V)
SEARCHES R.H. SIDE OF RECTANGLE FOR GIVEN VALUE
C
```

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```
DIMENSION XV(1),YV(1),X(1),Y(1),V(100,200)
TF (R,GT,T,AND,C,LT,T,OR,R,LT,T,AND,C,GT,T) 1,7
1 P1=YV(TA)
Q1=YV(TA+1)
XX=(P1+Q1)/2.
T1=B
T2=C
TF (JA,EQ,1) 2,3
2 R1=YV(JA+2)
T3=V(TA+1,JA+2)
CALL S0L33(XX,T,P1,Q1,P1,T1,T2,T3)
GO TO 6
3 TF (JA,EQ,1) 4,5
4 R1=YV(JA+1)
T3=V(TA+1,JA+1)
CALL S0L33(XX,T,P1,Q1,P1,T1,T2,T3)
GO TO 6
5 TF (V(TA+1,JA-1),LE,0,) GOTL 2
TF (V(TA+1,JA+2),LE,0,) GOTL 4
R1=YV(JA-1)
S1=YV(JA+2)
T3=V(TA+1,JA-1)
T4=V(TA+1,JA+2)
CALL S0L44(XX,T,P1,Q1,P1,S1,T1,T2,T3,T4)
6 NT=2
TX=IX+1
Y(TX)=XV(TA+1)
Y(TX)=XX
TA=IA+1
7 RETURN
END
C
C SUBROUTINE CDRC,D,T,XV,YV,Y=V(TA,JA,TX,NT,II,V)
C SEARCHES TOP SIDE OF RECTANGLE FOR GIVEN VALUE
C
DIMENSION XV(1),YV(1),X(1),Y(1),V(100,200)
TF (C,GT,T,AND,D,LT,T,OR,C,LT,T,AND,D,GT,T) 1,7
1 P1=XV(TA)
Q1=XV(TA+1)
XX=(P1+Q1)/2.
T1=D
T2=C
TF (IA,EQ,1) 2,3
2 R1=XV(TA+2)
T3=V(TA+2,JA+1)
CALL S0L33(XX,T,P1,Q1,P1,T1,T2,T3)
GO TO 6
3 TF (IA,EQ,II) 4,5
4 R1=XV(TA-1)
T3=V(TA-1,JA+1)
CALL S0L33(XX,T,P1,Q1,P1,T1,T2,T3)
GO TO 6
5 TF (V(TA-1,JA+1),LE,0,) GOTL 2
TF (V(TA+2,JA+1),LE,0,) GOTL 4
R1=XV(TA-1)
S1=XV(TA+2)
T3=V(TA-1,JA+1)
T4=V(TA+2,JA+1)
CALL S0L44(XX,T,P1,Q1,P1,S1,T1,T2,T3,T4)
6 NT=3
```

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```
    IX=IX+1
    X(TX)=YX
    Y(TX)=YY(JA+1)
    JA=JA+1
7  RETURN
END

C
C      SUBROUTINE DARD(A,T,XY,YY,X,Y,IA,JA,IX,NT,JJ,V)
C      SEARCHES L.H. SIDE OF RECTANGLE FOR GIVEN VALUE
C
C      DIMENSION XV(1),YY(1),X(1),Y(1),V(100,200)
C      TF (D.GT.T.AND.A.LT.T,OR,D.LT.T.AND.A.GT.T) 1,7
1  P1=YY(JA)
    Q1=YY(JA+1)
    XX=(P1+Q1)/2.
    T1=A
    T2=D
    TF (JA,EN,1) 2,3
2  R1=YY(JA+2)
    T3=V(IA,JA+2)
    CALL SOL33(XX,T,P1,Q1,P1,T1,T2,T3)
    GO TO 6
3  TF (JA,EN,JJ) 4,5
4  R1=YY(JA-1)
    T3=V(IA,JA-1)
    CALL SOL33(XX,T,P1,Q1,P1,T1,T2,T3)
    GO TO 6
5  TF (V(IA,JA-1),LE,0,) GOTO 2
    TF (V(IA,JA+2),LE,0,) GOTO 4
    R1=YY(JA-1)
    S1=YY(JA+2)
    T3=V(IA,JA-1)
    T4=V(IA,JA+2)
    CALL SOL44(XX,T,P1,Q1,P1,S1,T1,T2,T3,T4)
6  NT=4
    IX=IX+1
    X(TX)=YX(IA)
    Y(TX)=YY
    JA=IA+1
7  RETURN
END

C
C      SUBROUTINE SOL33(XX,T,P1,Q1,R1,T1,T2,T3)
C      POLYNOMIAL INTERPOLATION WITH 3 NODES
C
    XX=XX-P1
    X1=0.
    X2=Q1-P1
    X3=R1-P1
    PQ=X2
    XX2=X2*X2
    XX3=X3*X3
    TT=T-T1
    TT2=T2-T1
    TT3=T3-T1
    DT=XX2*X3-XX3*X2
    AA=(TT2*X3-TT3*X2)/DT
    BB=(XX2*TT3-XX3*TT2)/DT
    TX=TT
    TZ=TT2-TT
```

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```
1  TY=(AA+XX+RR)*XX-TT
  TU=TX+TY
  TF (TU) 2,5,3
2  Y2=XX
  TZ=TY
  GO TO 4
3  Y1=XX
  TX=TY
4  XU=(X1+X2)/2.
  U=ABS((XX-XU)/PQ)
  XX=XU
  TF (U,LT.,.005) 5,1
5  XX=XX+P1
  RETURN
  END
C
C  SUBROUTINE SCI44(XX,T,P1,Q1,R1,S1,T1,T2,T3,T4)
C  POLYNOMIAL INTERPOLATION WITH 4 NODES
C
  XX=XX-P1
  X1=0.
  X2=Q1-P1
  X3=R1-P1
  X4=S1-P1
  PQ=X2
  XX2=Y2+Y2
  XX3=Y3+Y3
  XX4=Y4+Y4
  XXX2=XX2*XX2
  XXX3=XX3*XX3
  XXX4=XX4*XX4
  TT=T-T1
  TT2=T2-T1
  TT3=T3-T1
  TT4=T4-T1
  DT=DT3(XXX2,YY2,X2,XXX3,YY3,X3,XXX4,YY4,X4)
  AA=DT3(TT2,XX2,X2,TT3,YY3,X3,TT4,XX4,X4)/DT
  RR=DT3(XXX2,TT2,XX2,XXX3,TT3,X3,XXX4,TT4,X4)/DT
  CC=DT3(XXX2,YY2,TT2,XXX3,YY3,TT3,XXX4,XX4,TT4)/DT
  TY=TT
  TZ=TT2-TT
1  TY=((AA+XX+RR)*XX+CC)*XX-TT
  TU=TX+TY
  TF (TU) 2,5,3
2  Y2=XX
  TZ=TY
  GO TO 4
3  Y1=XX
  TX=TY
4  XU=(Y1+Y2)/2.
  U=ABS((XX-XU)/PQ)
  XX=XU
  TF (U,LT.,.005) 5,1
5  XX=XX+P1
  RETURN
  END
C
C  FUNCTION DT3(A1,P1,C1,A2,P2,C2,A3,B3,C3)
C  CALCULATES DETERMINANT OF 3 BY 3 MATRIX
```

DT3=A1*B2+C3+A2*B3+C1+A3*B1+C2=A2*B1+C3=A3*B2+C1
RETURN
END

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PROGRAM BDYCHK

```
DIMENSION HX(100),HY(200),X(4),Y(4)
INTEGER BDR(199,10),BDZ(99,10)
DATA BLNK/4H /
101 FORMAT(1UF8.0)
102 FORMAT(20I4)
110 FORMAT(1H1)
121 FORMAT(1H ,A1,3HHX(,I3,3H) E,FB.3,4(A4,6X,3HHX(,I3,3H) E,FB.3))
131 FORMAT(1H ,A1,3HY(,I3,3H) E,FB.3,4(A4,6X,3HY(,I3,3H) E,FB.3))
202 FORMAT(1H ,I4,5(4X,5I4))
READ 102,NX,NY,NEPR,NEPZ
READ 102,IO,IN,JU,JN
NXM1=NX=1
NYM1=NY=1
READ 101,(HX(I),I=1,NX)
READ 101,(HY(J),J=1,NY)
READ 102,((BDR(I,J),J=1,NEPR),I=1,NYM1)
READ 102,((BDZ(I,J),J=1,NEPZ),I=1,NXM1)
HX0=HX(IU)
DO 140 I=10,IN
HX(I+1-IU)=HX(I)
DO 140 IK=1,NEPZ
IF (BDZ(I,IK).LT.2*JU) BDZ(I,IK)=2*J0
IF (BDZ(I,IK).GT.2*JN) BDZ(I,IK)=2*JN
140 BDZ(I+1-I0,IK)=BDZ(I,IK)=2*(JU-1)
NX=IN+1-I0
NXM1=NX=1
HY0=HY(JU)
DO 160 J=JU,JN
HY(J+1-JU)=HY(J)-HY0
DO 160 JK=1,NEPR
IF (BDR(J,JK).LT.2*IU) BDR(J,JK)=2*I0
IF (BDR(J,JK).GT.2*IN) BDR(J,JK)=2*IN
160 BDR(J+1-J0,JK)=BDR(J,JK)=2*(IU-1)
NY=JN+1-J0
NYM1=NY=1
PRINT 110
K1=0
NCUL=NXM1/50
GOTO 222
220 NCUL=NCOL=1
222 INK=NCUL*50
225 K1=K1+1
K2=K1+INK
PRINT 121,(BLNK,K,HX(K),K=K1,K2,50)
IF (K1.EQ.50,IN,K1,EW,NX) GOTO 229
IF (K2.EQ.NX) 220,225
229 PRINT 110
K1=0
NCUL=NYM1/50
GOTO 232
230 NCOL=NCOL=1
```

```
232 INK=NCUL*50
235 K1=K1+1
K2=K1+INK
PRINT 131,(HLNK,K,MY(K),K$K1,K2,50)
IF (K1,EW,50,UR,K1,EW,NY) GOTO 239
IF (K2,EW,NY) 230,235
239 PRINT 110
DO 250 J=1,NYM1
250 PRINT 202,J,(BDR(J,K),K=1,NEPR)
PRINT 110
DO 260 J=1,NXM1
260 PRINT 202,J,(BDZ(J,K),K=1,NEPZ)
CALL PLOTS (11,0,99)
CALL PLUT (0.,-14.,-3)
CALL PLUT(0.,0.5,-3)
XMAX=XMAX(NX)=MX(1)
YMAX=YMAX(NY)=MY(1)
FIRSTX=XMAX(1)
DELTAX=XMAX/10.
FIRSTY=YMAX(1)
DELTAY=DELTAX
YAX=YMAX*10./XMAX
CALL AXIS(0.,10.,6HZ=AXIS,+6,YAX,0.,FIRSTY,DELTAY)
CALL AXIS(0.,10.,6MM=AXIS,-6,10.,270.,FIRSTX,DELTAX)
X(3)=FIRSTX
X(4)=DELTAX
Y(3)=FIRSTY
Y(4)=DELTAY
DO 500 I=1,NYM1
Y(1)=MY(I+1)
Y(2)=MY(I)
DO 400 J=1,NEPR
IF (BDR(I,J),GT,2*NX) GOTO 500
L=BDR(I,J)/2
K=BDR(I,J)/2, + .5 - L
X(1)=XMAX=MX(L)
IF (K,GE,1) GOTO 350
X(2)=X(1)
GOTO 390
350 X(2)=XMAX=MX(L+1)
390 CALL LINE(Y,X,2,1,0,0)
400 IF (BDR(I,J),GE,2*NX) GOTO 500
500 CONTINUE
DO 700 I=1,NXM1
X(1)=XMAX=MX(I)
X(2)=XMAX=MX(I+1)
DO 600 J=1,NEPZ
IF (BDZ(I,J),GT,2*NY) GOTO 700
L=BDZ(I,J)/2
K=BDZ(I,J)/2, + .5 - L
Y(1)=MY(L)
IF (K,GE,1) GOTO 550
Y(2)=Y(1)
GOTO 590
550 Y(2)=MY(L+1)
```

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590 CALL LINE(Y,X,2,1,0,0)
600 IF (BDZ(I,J).GE.2*NY) GOTO 700
700 CONTINUE
    CALL PLOT(12.0,0.0,40)
    STOP
    END
```

PROGRAM EPSCHK

```
DIMENSION R(99,199),Z(99,199),EPSR(199,10),EPSZ(99,10)
INTEGER BDR(199,10),BDZ(99,10)
DATA EPSR/1990*0.0/,EPSZ/990*0.0/
DATA R/19701*1.0/,Z/19701*1.0/
102 FORMAT(2014)
104 FORMAT(16F5.0)
150 FORMAT (1H1,3X,32HN   NX   NY   R(NX,NY)   Z(NX,NY))
155 FORMAT (1H ,315,2F10.3)
161 FORMAT (1H0,16X,2HNU)
162 FORMAT (1H0,12X,10HDIELECTRIC)
163 FORMAT (1H0,10X,15HINCCONSISTENCIES)
175 FORMAT(1H1,5X,1H+,24(I4,1X))
176 FORMAT(6X,1H+,24(I4,1X))
180 FORMAT(6X,1H+,24(5H----+--))
185 FORMAT(1X,I4,2H +,24F5.1)
    READ 102,NX,NY,NEPR,NEPZ
    NXM1=NX-1
    NYM1=NY-1
    READ 102,((BDR(I,J),J=1,NEPR),I=1,NYM1)
2 READ 102,KU,KN,KK
    READ 104,(EPSR(KU,K),K=1,KK)
    IF (KU,EQ,KN) GOTO 4
    K=KU+1
    DO 3 I=K,KN
    DO 3 K=1,KK
3 EPSR(I,K)=EPSR(KU,K)
4 IF (K,EQ,NEPR) GOTO 5
    K=KK+1
    DO 45 I=K0,KN
    DO 45 J=K,NEPR
45 EPSR(I,J)=EPSR(I,KK)
5 IF (KN,LT,NYM1) GOTO 2
    READ 102,((BDZ(I,J),J=1,NEPZ),I=1,NXM1)
6 READ 102,KU,KN,KK
    READ 104,(EPSZ(KU,K),K=1,KK)
    IF (KU,EQ,KN) GOTO 8
    K=KU+1
```

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```
DO 7 I=K1,KN
DO 7 K=1,KK
7 EPSZ(I,K)=EPSZ(KU,K)
8 IF (KK.EQ.NEPZ) GOTO 9
KPKK+1
DO 89 I=KU,KN
DO 89 J=K1,NEPZ
89 EPSZ(I,J)=EPSZ(I,KK)
9 IF (KN.LT.NXM1) GOTO 6
DO 20 I=1,NYM1
M=0.
K2=0
DO 20 J=1,NEPK
IF (M=K2.GT.0.) K2=K2+1
K1=K2+1
M=BDR(I,J)/2.-1.
K2=M
IF (K2.LT.K1) GOTO 20
DO 10 K=K1,K2
10 R(K,I)=EPSR(I,J)
20 CONTINUE
DO 40 I=1,NXM1
M=0.
K2=0
DO 40 J=1,NEPZ
IF (M=K2.GT.0.) K2=K2+1
K1=K2+1
M=BDZ(I,J)/2.-1.
K2=M
IF (K2.LT.K1) GOTO 40
DO 30 K=K1,K2
30 Z(I,K)=EPSZ(I,J)
40 CONTINUE
N=0
PRINT 150
DO 60 I=1,NXM1
DO 60 J=1,NYM1
IF (R(I,J).EQ.Z(I,J)) GOTO 60
N=N+1
PRINT 155,N,I,J,R(I,J),Z(I,J)
IF (N.GE.1000) GOTO 70
60 CONTINUE
IF (N.GT.0) GOTO 70
PRINT 161
PRINT 162
PRINT 163
70 CONTINUE
210 M2=0
M1=50
220 M2=M2+50
IF (M2.LE.NY) GOTO 225
M1=NY+50-M2
M2=NY
225 N2=0
230 N1=N2+1
```

```

N2=N2+24
IF (N2,GT,NX) N2=NX
PRINT 175,(K,K=N1,N2)
PRINT 180
DO 250 J=1,M1
  I=M2+1-J
250 PRINT 185,I,(R(K,I),K=N1,N2)
  PRINT 180
  PRINT 176,(K,K=N1,N2)
  IF (N2,LT,NX) GOTO 230
  IF (M2,LT,NY) GOTO 220
260 M2=0
  M1=50
270 M2=42+50
  IF (M2,LE,NY) GOTO 275
  M1=NY+50-42
  M2=NY
275 N2=0
280 N1=N2+1
  N2=N2+24
  IF (N2,GT,NX) N2=NX
  PRINT 175,(K,K=N1,N2)
  PRINT 180
  DO 300 J=1,M1
    I=M2+1-J
300 PRINT 185,I,(Z(K,I),K=N1,N2)
  PRINT 180
  PRINT 176,(K,K=N1,N2)
  IF (N2,LT,NX) GOTO 280
  IF (M2,LT,NY) GOTO 270
  STOP
END

```

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